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Isokite, $CaMgPO_4F$, a new mineral from Northern Rhodesia.

(With Plate XVIII.)

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[Read March 24, 1955.]

Introduction.

THE mineral, for which the name isokite is now proposed, occurs in the carbonatite plug which forms Nkumbwa Hill (lat. 10° 10′ S. long. 32° 51′ E.), 15 miles east of Isoka (pronounced Isōka) in Northern Rhodesia. A preliminary account of this interesting mineral locality has already been published (Reeve and Deans, 1954) and a more detailed account is now in preparation, so that only the main features of the occurrence need be mentioned here. The carbonatite plug or pipe, 0·6 by 1 mile across and rising to a height of 1000 feet above the surrounding country, pierces granitic and micaceous gneisses which are fenitized to a distance of 500 yards from the walls of the pipe, but, unlike the classic carbonatite complexes, no intrusive alkalic rocks are exposed. Near the margin of the intrusion the carbonatite contains abundant fragments of fine-grained phlogopite-rock, which can be shown to represent metasomatized fragments of brecciated gneiss.

The carbonatite consists of ankeritic dolomite (ω 1·680–1·695), usually coarsely crystalline and practically free from calcite, and contains only small percentages of silicates, chiefly phlogopite and alkali-amphiboles. In Brögger's terminology the rock is a rauhaugite. The principal accessory minerals are apatite (including strontian fluorapatite), isokite, pyrite, magnetite, ilmenite, baryte, monazite, pyrochlore,

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and rather rare sellaite. Hydrous minerals are conspicuously absent. Geochemically, the carbonatite is characterized by relatively high concentrations of Mg, Ca, P, F, Mn, Sr, Ba, La-Ce group, and Nb, while the surrounding metasomatic phlogopite-rocks and sodic fenites indicate outward migration of both K and Na. The Nkumbwa plug appears to be quite isolated, the nearest carbonatites yet recorded being Panda Hill in Tanganyika, 90 miles to the north, and Kangankunde Hill in Nyasaland, 380 miles to the south. Mineralogically, Nkumbwa is much more akin to Kangankunde than to Panda Hill.

Most of the specimens used in the present study were collected by Mr. K. A. Phillips of the Northern Rhodesia Geological Survey during his mapping of the hill in 1952, but additional material was obtained by one of the authors (Deans) during a brief visit in 1953 when it was already clear that the 'white phosphate' merited detailed study. When the optical properties and chemical composition of the mineral had been established, indicating a new mineral species, Mr. McConnell was invited to undertake the X-ray investigations.

Physical properties.

Isokite is visible in a large minority of the carbonatite specimens from Nkumbwa as small white, buff or faintly pinkish spots or patches in the grey or brown (oxidized) ankeritic rocks, and with a hand-lens appears as fibrous spherulites with silky lustre, or less frequently as radiating aggregates of thin crystalline plates with slightly pearly lustre. In thin section the spherulites, commonly 0·5 to 1 mm. in diameter but sometimes as small as 0·05 mm., are usually finely fibrous (pl. XVIII, fig. 1) and characterized by moderate birefringence and negative elongation. Rarer specimens contain coarser spherulites up to 2 or even 3 mm. in diameter, built up of thin plates radiating from the centre (text-figs. 1 and 2). Those plates normal or steeply inclined to the plane of the section show straight extinction and negative elongation, but in one sector of each spherulite there are often two or three plates lying almost in the plane of the section and these show lower birefringence, a clear biaxial bisectrix interference figure which is positive, and oblique extinction. Consequently these coarser spherulites do not show between crossed nicols the symmetrical black cross characteristic of fibrous spherulites, but a distinctly distorted one.

The optical properties of the mineral have been measured from the thin plates split from these coarser spherulites, and are α 1·590, β 1·595, γ 1·615 (all $\pm$0·002), biaxial positive with Bx_a normal to the cleavage

plates, and 2V 51–51½° (±2°) (universal-stage measurements by Dr. J. B. Allen), dispersion $r > v$. There is a single very good cleavage on which the plates separate, and only imperfect partings in other, sometimes divergent, directions. The plates attain a maximum width of

Fig. 1. Bladed spherulites of isokite. Crossed nicols. ×40.
Fig. 2. Large bladed spherulite of isokite, and (lower half) basal plates of strontian fluorapatite with interstitial dolomite (dark). Crossed nicols. ×40.

about 0·3 mm. and terminate obliquely in 3 or 4 edges. A typical selection of these terminated plates is illustrated in fig. 3, fig. 3c showing a complete individual with characteristic elongation, whereas the remainder are broken plates, as the great majority break at their widest part when the spherulites are split up. The peripheral angles have been measured with a Dick-Swift microscope, and the edges indexed from the X-ray crystallographic data (see below), measured and calculated angles being in good agreement as the following comparison shows:

	(001):(101).	(101):(100).	(100):(10$\bar{1}$).	(10$\bar{1}$):(10$\bar{2}$).
Measured	150°	152–3°	126–7°	146–7°
Calculated	148½	153	126½	147

Very narrow prism and pyramid faces are visible bevelling terminal edges on some plates, but it was not possible to measure these. The plates are flattened parallel to (010) and elongated parallel to a, and the extinction angle between X and the edge (100), i.e. $\alpha:c$ is about 32°.

Extinction is frequently rather wavy, however, partly owing to superposition of thin plates. The optical orientation is shown in fig. 3D.

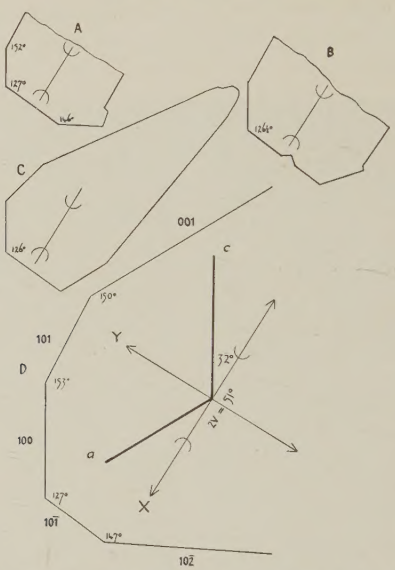

FIG. 3. Thin crystal plates of isokite split from spherulites, lying on (010) and showing measured angles between boundary edges, and the optical orientation.

The specific gravity of the isokite, determined by suspension in heavy liquids, ranges from about 3·15 to 3·27, with a mean value of about 3·22, the fibrous material being appreciably lighter than the crystalline plates, the specific gravity of which lies close to 3·27. Hardness is difficult to measure on such small thin crystals, but is certainly more than 4 and probably about 5 on Mohs's scale. In most specimens the isokite displays a blue fluorescence under long wave (3650 Å.) ultra-violet light. The sellaite from this locality shows a rather similar fluorescence, but is of much rarer occurrence. The mineral dissolves slowly in cold hydrochloric acid, and rapidly in warm acids. It is evidently more readily acid-soluble than the associated apatite, for whereas the fine red soils on Nkumbwa Hill contain abundant apatite liberated from the underlying carbonatite, only very small amounts of isokite occur in the soils, except among the coarser rubble.

CHEMICAL COMPOSITION.

For the separation of sufficient isokite for detailed chemical analysis, a specimen (DNR.5) from the north-eastern corner of the hill was

selected. This is a brown ankeritic dolomite-rock containing abundant white spherulites of isokite about 2 mm. in diameter, many of them coarsely crystalline, and only minor quantities of strontian fluorapatite, a little secondary calcite, and traces of monazite. In crushing the rock the isokite powders very readily, and when most of the material had passed a 60 British Standard mesh sieve, the finest fraction, −240 mesh, was found to be very rich in isokite and was selected for further concentration. After washing off the finest dust the powder was centrifuged in methylene iodide–benzene mixtures and the fraction of density 3·16 to 3·30 was retained. A small amount of material contaminated with ankeritic and other ferruginous impurities was finally removed by means of a Cook magnetic separator, and left a product suitable for chemical analysis. This concentrate, weighing 4 gm., contained only a little ankeritic dolomite and apatite as impurities, and was analysed by Mr. Pickup with the results shown in table I.

TABLE I. Chemical composition of isokite.

	1.	2.	3.	4.	5.	6.
CaO	30·72	0·64	0·51	29·57	30·61	31·45
SrO	1·65	—	0·05	1·60	1·66	—
BaO	0·21	—	—	0·21	0·22	—
Rare-earths	0·16	—	—	0·16	0·16	—
MgO	21·58	0·40	—	21·18	21·93	22·60
FeO	0·49	0·08	—	0·41	0·42	—
MnO	0·13	—	—	0·13	0·13	—
P_2O_5	37·76	—	0·40	37·36	38·68	39·79
F	9·55	—	0·03	9·52	9·86	10·65
$H_2O+300°$ C. ...	0·46	—	—	0·46	0·48	—
$H_2O-300°$ C. ...	0·26	—	—	—	—	—
CO_2	1·02	1·02	—	—	—	—
Acid insol.	0·10	—	—	—	—	—
	104·09	2·14	0·99	100·60	104·15	104·49
Less O for F	4·02			4·01	4·15	4·49
	100·07			96·59	100·00	100·00

1. Analysis of concentrate from specimen DNR.5. Analyst, R. Pickup.
2. Constituents assigned to ankeritic dolomite.
3. Constituents assigned to strontian fluorapatite.
4. Composition of isokite.
5. Composition of isokite recalculated to 100 per cent.
6. Composition of $CaMgPO_4F$.

The principal impurity, ankeritic dolomite, has been corrected for by assuming that all the CO_2 can be assigned to this mineral. This is

certainly largely true, and the additional possibility that CO_3OH groups might replace PO_4 groups to a minor extent in isokite (as in carbonate-apatites), having no direct evidence in its favour, is not considered further. The apatite content appears to be very small, and although it cannot be estimated accurately, 1 % is assumed to be present. The constituents assigned to these impurities, based on previous analyses from this locality, are shown in table I, and after deducting these together with the water lost in 3 hours at 300° C. (regarded as adsorbed water) and the insoluble residue, the inferred composition of the isokite is as shown in columns 4 and 5. The analysis leaves no doubt that isokite is essentially $CaMgPO_4F$, with only minor substitution of calcium by strontium and of fluorine by hydroxyl. The strontium content is not to be regarded as essential, for it was to be anticipated in an environment such as Nkumbwa where strontium is relatively abundant, as in many carbonatites. The associated strontian fluorapatite contains even more of this element, an analysis by Mr. Pickup showing 4·72 % SrO. It may be mentioned here that some isokite specimens are somewhat stained with manganese to a pink or rhododendron tint, while others are speckled with green, owing to the presence of finely divided green monazite. Until this colour variegation was understood it led to the belief that rare-earths and manganese might be essential constituents of isokite, but this is clearly not the case.

A search of the literature reveals no mineral analysis sufficiently similar to that of isokite to warrant detailed comparison. Strunz (1938), however, has suggested that the mineral cryphiolite described by A. Scacchi (1888) from ejected blocks from Vesuvius was in fact $CaMgPO_4F$, and monoclinic, isostructural with tilasite ($CaMgAsO_4F$). This was contrary to the general belief that cryphiolite is a calcic variety of wagnerite, Mg_2PO_4F, but it was obviously desirable to investigate this point before naming the Rhodesian mineral. The fact that cryphiolite was found in close association with sellaite (belonesite of Scacchi), and that Vesuvius and Nkumbwa are the only localities from which sellaite is recorded in a volcanic environment, made this question appear even more important. Through the kindness of Professor A. Scherillo of Naples one of Scacchi's original cryphiolite crystals was obtained, and is at present being examined by X-ray methods in the British Museum, Department of Mineralogy. The X-ray evidence indicates that cryphiolite is related to neither wagnerite, tilasite, nor isokite, and so it need not be considered further in the present connexion, although it will be of interest to learn what it really is.

X-ray investigation.

The single crystals used for the X-ray study of isokite were selected from the crushed spherulites of specimen DNR.5. Preliminary examination, by single-crystal X-ray technique, of a number of the small flakes produced showed that most of these comprised several distinct individuals in parallel growth. Subsequently a small crystal was isolated which showed one main set of reflections with additional weaker reflections due to the presence of a second individual. This crystal was used for the single-crystal study described below.

Single-crystal photographs showed that the mineral is monoclinic and that the good cleavage is (010). The cell dimensions and space group were determined from a *b*-axis oscillation photograph and zero, first, and fourth layer-line Weissenberg photographs for the *b*-axis. The values obtained for the cell dimensions were, *a* 6·52, *b* 8·75, *c* 7·51 Å., all ±0·05 Å., and β 121° 28′±12′. The corresponding axial ratios are $a:b:c = 0{\cdot}745:1:0{\cdot}858$. Among the general reflections (*hkl*) only those with $(h+k)$ even were observed. Examination of the (*h*0*l*) reflections showed that additional absences occurred when *l* was odd. The mineral gave negative results when tested for pyroelectricity; consequently the space group is $C2/c$.

Table II. Unit-cell contents of isokite.

Analysis.		Atomic ratios.		Unit-cell contents.	
CaO	29·57	Ca ...	0·5272	3·929	
SrO	1·60	Sr ...	0·0154	0·115	4·061
BaO	0·21	Ba ...	0·0014	0·010	
$(Ce,La)_2O_3$ ...	0·16	Ce,La	0·0010	0·007	
MgO	21·18	Mg ...	0·5253	3·914	
FeO	0·41	Fe ...	0·0057	0·042	3·969
MnO	0·13	Mn ...	0·0018	0·013	
P_2O_5	37·36	P ...	0·5262	3·921	3·921
F	9·52	F ...	0·5011	3·734	4·115
OH	0·87	OH	0·0511	0·381	
	101·01	O ...	2·1176	15·780	15·780
Less O for F,OH	4·42			31·846	
	96·59				

In table II the cell contents of isokite have been calculated from the observed density, 3·27, and the chemical analysis corrected for impurities. The formula unit is $CaMgPO_4F$, with minor partial substitutions, and the unit cell contains four formula units. The calculated

density of isokite is 3·29. X-ray powder data for isokite have been tabulated in table III.

TABLE III. X-ray powder data for isokite.

4·38	w	1·962	w	1·522	vvw	1·202	vvw
3·62	vw	1·946	vw	1·510	vvw	1·171	vvw
3·45	vw	1·886	vw	1·495	vvw	1·115	w
3·185	vvs	1·872	w	1·479	m	1·084	vvw
3·023	vvs	1·837	vvw	1·453	vvwb	1·078	vvw
2·887	vvw	1·807	m	1·428	wb	1·052	w
2·784	m	1·740	vvw	1·392	w	1·049	w
2·630	vvs	1·720	s	1·388	w	1·046	w
2·586	m	1·705	m	1·344	w	1·034	vvw
2·487	vw	1·684	vvw	1·313	w	1·017	vw
2·301	s	1·671	vvw	1·303	vvw	1·006	vvw
2·222	mb	1·656	m	1·276	w	0·959	w
2·105	m	1·602	vvw	1·234	w	0·875	w
2·069	m	1·557	m	1·225	vw	0·828	vvw
2·041	m	1·539	vvw	1·211	vvw	0·811	vvw

X-ray powder data for the analysed sample of isokite (DNR.5A). The *d* spacings are given in Å. units and the relative intensities were estimated visually on the decreasing scale vvs, vs, s, m, w, vw, vvw, b = broad and diffuse. The X-ray powder photograph was taken on a 19-cm. camera using Cu-$K\alpha$ radiation.

To ensure that the X-ray and optical data should relate to the same material the single crystal used for the X-ray work was examined optically. The refractive indices obtained were α 1·590, β 1·594, and γ 1·614, all $\pm$0·002, with γ parallel to *b* and $\alpha:c$ +32°.

Isokite is homologous with the minerals of the tilasite group (Richmond, 1940, p. 464). The cell dimensions and chemical composition of the minerals of this group are compared in table IV.

TABLE IV. Comparison of members of the tilasite group.

	Durangite* $NaAlAsO_4F$.	Tilasite† $CaMgAsO_4F$.	Sphene‡ $CaTiSiO_4(O,OH,F)$.	Isokite $CaMgPO_4F$.
a	6·53	6·66	6·55	6·52 Å.
b	8·46	8·95	8·70	8·75
c	7·30	7·56	7·43	7·51
β	119° 22′	121° 0′	119° 43′	121° 28′
Cell contents	4	4	4	4
Space group	*C*2/*c*	*C*2/*c*	*C*2/*c*	*C*2/*c*

* Kokkoros (1938, p. 39) with transformation of axes.
† Strunz (1937, p. 10).
‡ Zachariasen (1930, p. 7), with formula as modified by Sahama (1946, p. 106).

Strunz (1949, p. 112) also includes in this group scholzite, $Ca_3Zn(PO_4)_2(OH)_2.H_2O$, which has comparable cell dimensions but is pseudo-orthorhombic ($\beta \sim 90°$), so that its position in the group is rather anomalous.

Paragenesis.

In the Nkumbwa rocks isokite has so far been found in intimate association with dolomite, strontian fluorapatite, monazite, phlogopite, and pyrochlore. Sellaite and isokite have not as yet been found in the same thin section, although they occur together in the same bulk samples, but as sellaite has been seen in only a few sections this point may not be very significant. In the main, isokite appears to belong to a late stage of metasomatic activity which enriched the intrusive dolomite plug with fluophosphates, strontium, rare-earths, and niobium. Often isokite and monazite are intimately associated, both minerals occurring as spherulites which replace coarsely crystalline dolomite along the rhombohedral cleavage planes (pl. XVIII, fig. 1). The conversion of dolomite to isokite by replacement of carbonate by fluophosphate groups would involve a shrinkage in volume of about 15 % and occasionally there are signs that this may have taken place, in that the spherulites sometimes project into small cavities. Generally, however, this late metasomatism was complex, and the details of the process are not yet fully understood. In the xenolithic inclusions of phlogopite-rock (metasomatized gneiss) apatite is common but isokite is rather infrequent, although it may be plentiful in the immediately adjacent dolomite. The weathering of the Nkumbwa carbonatite has been accompanied in places by extensive silicification, and this has sometimes left isokite spherulites completely enveloped in secondary quartz with colloform textures.

Sahama (1945) has called attention to the rarity of the magnesium minerals sellaite MgF_2 and wagnerite Mg_2PO_4F in contrast to the abundance of their calcium equivalents, fluorite and apatite, and has discussed some of the reasons for this. Similar considerations may account for the rarity of isokite, and prompted inquiry as to what special circumstances have favoured its occurrence at Nkumbwa. One obvious condition for its formation is an abundance of fluorine, for isokite contains about three times as much fluorine as fluorapatite. This was clearly present at Nkumbwa where in addition to the large amount of fluorine contained in isokite, the phlogopite-rocks (containing 5 % F) and apatite (3·4 % F) must together contain a similar major quantity, with lesser amounts present as sellaite (61 % F), pyrochlore, &c. A second factor is the high magnesium/calcium ratio which was apparently maintained throughout all the intrusive and metasomatic stages represented at the present erosion level of the plug, indicating circumstances quite different from the general trend at Alnö where, according to Eckermann

(1948), the carbonatites underwent progressive dedolomitization with consequent later enrichment in calcium. At Nkumbwa there are no calcitic carbonatites (sövites), dolomite, usually ankeritic, being practically the only carbonate present, and what little calcite does occur appears to be largely of supergene origin. The only evidence of dedolomitization recognized so far is in the form of local enrichments of apatite in the carbonatite immediately surrounding the phlogopite-rock inclusions. This relative paucity of calcium and abundance of phosphate probably also account for the absence of fluorite at Nkumbwa, despite the abundance of fluorine.

Acknowledgements.—This work forms part of a joint investigation of the Nkumbwa Hill pyrochlore deposits undertaken by the Northern Rhodesia Geological Survey Department and the Mineral Resources Division of Colonial Geological Surveys, London. Thanks are due to the Department of Mineralogy, University of Cambridge, for arranging for Mr. McConnell to undertake the X-ray examination of this new mineral, and to the Department of Mineralogy, British Museum, for assistance at various stages of the work. The authors are indebted to several colleagues for help and advice.

References.

Eckermann (H. von), 1948. The alkaline district of Alnö island. Sveriges Geol. Undersök., Ser. Ca., no. 36, 176 pp. [M.A. **11**–27.]

Kokkoros (P.), 1938. Über die Struktur des Durangit $NaAlF(AsO_4)$. Zeits. Krist., vol. 99, pp. 38–49. [M.A. **7**–237.]

Reeve (W. H.) and Deans (T.), 1954. An occurrence of carbonatite in the Isoka district of Northern Rhodesia. Colonial Geol. Min. Res. London, vol. 4, pp. 271–281. [M.A. **12**–537.]

Richmond (W. E.), 1940. Crystal chemistry of the phosphates, arsenates and vanadates of the type $A_2XO_4(Z)$. Amer. Min., vol. 25, pp. 441–479. [M.A. **8**–11.]

Sahama (Th. G.), 1945. Abundance relation of fluorite and sellaite in rocks. Ann. Acad. Sci. Fennicae, ser. A, III, no. 9, 20 pp. [M.A. **9**–258.]

—— 1946. On the chemistry of the mineral titanite. Compt. Rend. Soc. Géol. Finlande, no. 19 (Bull. Comm. Géol. Finlande, no. 138), pp. 88–120. [M.A. **10**–302.]

Scacchi (A.), 1888. Sopra un frammento di antica roccia vulcanica inviluppato nella lava Vesuviana del 1872. Atti Accad. Sci. Napoli, ser. 2, vol. 1, no. 5.

Strunz (H.), 1937. Titanit und Tilasit. Über die Verwandtschaft der Silikate mit den Phosphaten und Arsenaten. Zeits. Krist., vol. 96, pp. 7–14. [M.A. **7**–92.]

—— 1938. Isomorphie zwischen Tilasit, Durangit und Cryphiolith. Centr. Min., pp. 59–60.

—— 1949. Mineralogische Tabellen. 2nd edit., p. 168. [M.A. **11**–2.]

Zachariasen (W. H.), 1930. The crystal structure of titanite. Zeits. Krist., vol. 73, pp. 7–16. [M.A. **4**–281.]

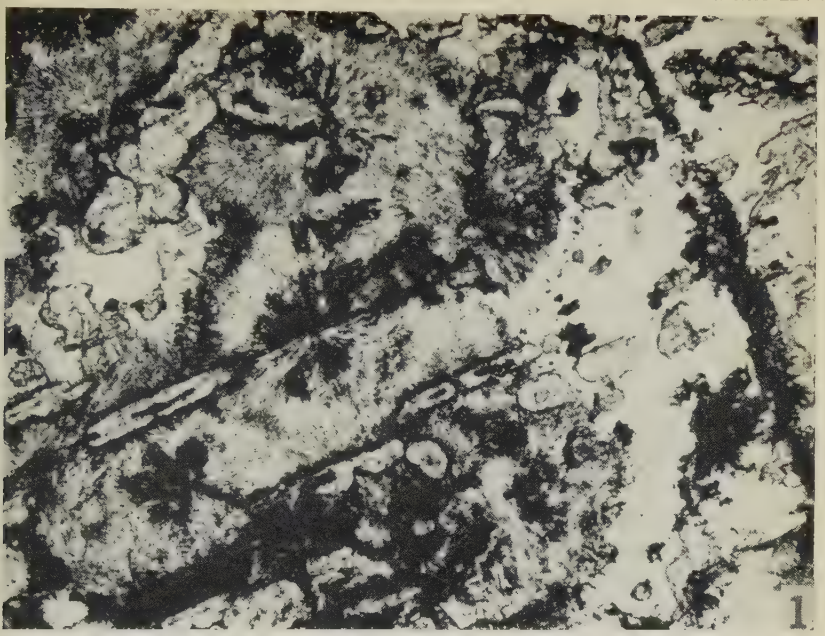

FIG. 1. Large fibrous spherulites of isokite, darkened by inclusions, and smaller elongated spherulites of monazite along dolomite cleavages

FIG. 2. Spherulites of isokite (top left and bottom right), and smaller spherulites of monazite showing black cross and concentric extinction bands.

Wairakite, the calcium analogue of analcime, a new zeolite mineral.

By A. Steiner.

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[Taken as read March 24, 1955.]

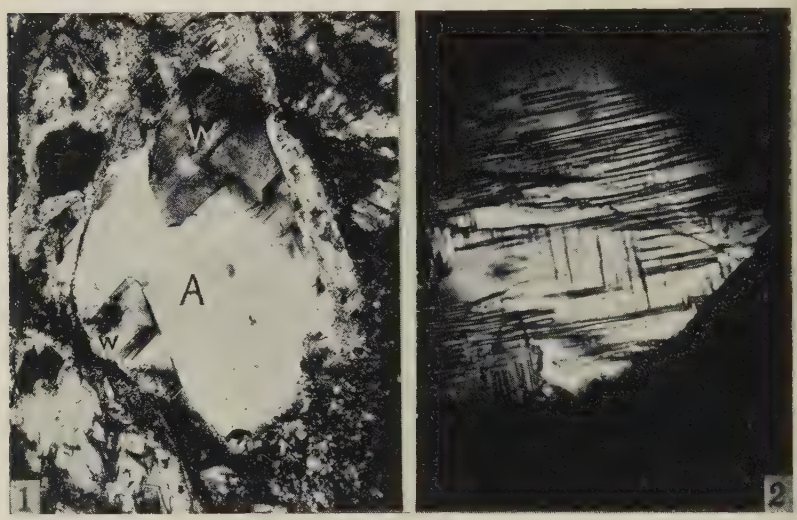
Introduction.

During the study of hydrothermal alteration of cores recovered from holes drilled at Wairakei during the exploration for geothermal steam, an unusual zeolite mineral was found. Optical, chemical, and X-ray data indicate that this zeolite is a new mineral, the calcium analogue of analcime. The name wairakite is given to the new mineral after the locality Wairakei in New Zealand. Wairakei is situated in the central part of the North Island, approximately 4 miles north-north-east from Lake Taupo, in an active volcanic region. The material was submitted to Dr. D. S. Coombs, Department of Geology, University of Otago, Dunedin, for an investigation of its X-ray crystallography. The results of his study are given in a paper published in the present number of this magazine. I take this opportunity of thanking Dr. Coombs for his ready co-operation.

Geological occurrence.

Wairakite occurs in tuffaceous sandstones and breccias, vitric tuffs and ignimbrite which originally had a similar chemical composition, i.e. of a plagioclase-rhyolite. All these rocks, Pliocene to Pleistocene in age, have been and are still being altered by hydrothermal fluids (Steiner, 1953). The new mineral has been found in drill cores obtained from levels ranging from 600 to 2890 feet and in rocks ejected by steam from some of the drill holes. In drill cores it is generally of microscopic grain-size, and its amount varies approximately from 2 to 15 %. It replaces andesine phenocrysts (fig. 1) and fills pores, cavities, and veinlets. In one core only, from hole 19 at a depth of 2890 feet, a white incrustation made up of wairakite has been noted. On the other hand, rock fragments ejected by steam from drill hole 19 (May 1954) often contain megascopic veinlets and fractures, 0·5 25 mm. thick, which are lined with drusy subhedral crystals or completely filled with massive

aggregates of wairakite. One of these ejected fragments (P 13871)[1] is made up of exceptionally large subhedral crystals of wairakite, 15 mm. across, implanted on a base consisting of calcite and aragonite (fig. 3). Some of the larger crystals show occasionally octahedral- or icositetrahedral-like faces.



Photomicrographs of wairakite, New Zealand.

Fig. 1 Primary andesine (A) partly replaced by wairakite (W) in rhyolitic breccia at 1855 feet (drill hole no. 18). Crossed nicols. ×73.

Fig. 2. Grain of wairakite showing two sets of twin lamellae at right angles. Crossed nicols. ×150.

Physical properties.

In hand-specimen wairakite is colourless to white, and has a vitreous lustre, grading to almost dull. In transmitted light it is always colourless. The streak is white, and the mineral is brittle. Other physical properties and the corresponding values for analcime are as follows:

	Wairakite.	Analcime.
Specific gravity	2·26	2·22–2·29
Fusibility	2½	2½
Hardness	5½–6	5–5½

Although wairakite filling microscopic pores does not show any cleavage, two cleavage-like lines probably parting, intersecting at right

[1] The number refers to specimens and microscopic sections in the New Zealand Geological Survey, Wellington.

angles and parallel to two sets of twinning lamellae (fig. 2), can be occasionally observed on powdered material obtained by crushing a megascopic crystal. Moreover, Dr. Coombs observed in an orientated section cut parallel to (100) a cleavage bisecting the angles between mutually perpendicular sets of twin lamellae.

Essential optical properties of wairakite are: α 1·498±0·001, γ 1·502± 0·001, $\gamma-\alpha = 0{\cdot}004$, $2V\gamma$ (apparently on single lamellae) variable 70–105°, average near 90°, weak $r > v$ about γ.

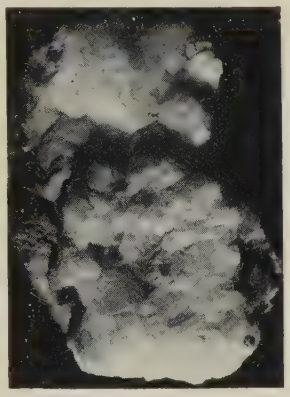


Fig. 3. Drusy subhedral crystals of wairakite, ejected from drill hole no. 19. ×2.

The indices of refraction have been determined with sodium-light and standard immersion liquids. The mineral is distinctly birefringent, no isotropic patches have been observed in contrast with birefringent analcime from Låven, Norway (Klein, 1897), and Loch Borolan, Scotland (Stewart, 1941). Polysynthetic twinning lamellae, commonly spindle shaped, are a conspicuous diagnostic property, and two sets of twinning lamellae, enclosing an angle of 90°, can often be observed (fig. 2). In studying thin sections no crystal outlines have been found. For this reason, the two sets of twinning lamellae in fig. 4 are orientated to hypothetical crystal faces, two of them being parallel to the twinning planes.

The amount of water given up at various temperatures as determined by J. A. Ritchie is as follows:

Temperature.	Loss of water in % by weight.
Between 110 and 380° C. ...	4·23
„ 380 and 800° ...	4·09
Above 800°	0·03
Total	8·35

These data suggest a continuous dehydration curve characteristic of zeolites.

Chemical properties.

Wairakite gelatinizes with hydrochloric acid, and this decomposition is increased by heating. For chemical analysis a subhedral crystal was

crushed and powdered. A sample of the powdered material was examined under the microscope for its purity. Because no other mineral was noticed the analysed sample is considered to be of high purity. The chemical composition is given in table I, which also shows that the calculated formula is very close to $CaO.Al_2O_3,4SiO_2.2H_2O$.

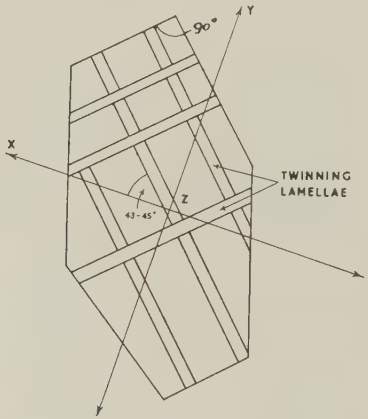


Fig. 4. Optical orientation in relation (at 43–45°) to two perpendicular sets of twin lamellae in wairakite. (Crystal outline assumed.)

Table I. Chemical analysis and molecular ratios of wairakite.

(Analyst, J. A. Ritchie, Dominion Laboratory, Wellington.)

SiO_2	...	55·9	0·932	932	4·08
Al_2O_3	...	23·0	0·225	225	0·98
CaO	...	11·7	0·209	228	1·00
SrO	...	0·05	0·0005		
Na_2O	...	1·06	0·017		
K_2O	...	0·16	0·002		
Cs_2O	...	0·017	—	—	—
Rb_2O	...	0·0003	—	—	—
H_2O+	...	8·35	0·472	472	2·07
H_2O-	...	0·15	—	—	—
		100·39			

According to the theory advanced by Winchell (1925) zeolites are characterized as follows:

(*a*) Ratio $Al_2O_3:CaO+Na_2O+K_2O = 1:1$.

(*b*) Ratio $Al+Si:O = 1:2$.

(*c*) Replacement of sodium by calcium occurs in the way that NaSi is substituted by CaAl; substitution under control of valency takes place only to a minor extent.

From table 1 it can be seen that the corresponding ratios (*a* and *b*) are in agreement with this theory. However, when the formulae of analcime and wairakite are compared, it is evident that in wairakite sodium is replaced by calcium under valency control only, the ratio Al:Si being constant in contrast with Winchell's theory (*c*).

Formation of wairakite.

As wairakite invariably occurs in hydrothermally altered rocks which are still being affected by hydrothermal fluids, its hydrothermal origin can hardly be doubted. The temperature measured in the vertical range in which wairakite has been observed ranges from 200 to 250° C., and the calculated hydrostatic pressure from 55 to 265 atmospheres. The alkaline character of hydrothermal waters in the drill holes at Wairakei as established by S. H. Wilson,[1] Dominion Laboratory, Wellington, indicates that wairakite, similarly to other zeolites, forms in an alkaline environment, but the prevailing pH is not known. Because the ratio of CaO to SiO_2 is comparatively high, hydrothermal solutions with excess of lime and deficient in silica can be postulated as being responsible for the formation of wairakite. There is no clue as to when the hydrothermal activity commenced.

From the rare occurrence of wairakite in nature it can be inferred that this mineral requires for its formation a definite set of chemical and physical conditions of a rather restricted range. At Wairakei the occurrence of this mineral suggests that the comparatively high temperature (200–250° C.) prevailing at a relatively shallow depth (600–2890 feet) is the controlling factor, other conditions being equal.

Microscopic investigation indicates that wairakite forms by: (*a*) Hydrothermal replacement and recrystallization of andesine; in this case the required constituents are available in a reactive state, partly in the andesine, and partly in hydrothermal waters. (*b*) Crystallization from hydrothermal solutions, filling pores and cavities; hydrothermal solutions provide all the necessary constituents.

There is no suggestion of its being formed by ion-exchange. In this connexion it is interesting to compare the formation in nature with the attempted syntheses of calcium-analcime, chemically analogous to wairakite. Two kinds of hydrothermal synthesis have been attempted: (*a*) synthesis by ion-exchange; (*b*) crystallization from reactive components. The synthesis of calcium-analcime by ion-exchange from analcime

[1] Personal communication.

(Barrer, 1950) succeeded to a limited extent only; it is not relevant to the formation of wairakite, though of importance from a structural point of view. On the other hand, hydrothermal crystallization of calcium-analcime attempted by Noll (1936, *a*, *b*) and of analcime, successfully carried out by both Barrer (1949) and Noll (1936*a*), is imitative of the formation of wairakite in nature. Noll used, for the attempted synthesis of calcium-analcime, hydrated alumina, silica gel, and a solution of $Ca(OH)_2$, the ratio $CaO:Al_2O_3:SiO_2$ being 1:1:4. The experiment was conducted at a temperature of 300° C. with a corresponding saturated vapour pressure of 87 atmospheres. The reaction time was between 15 and 24 hours. Unfortunately it is not known whether Noll really succeeded in his synthesis of calcium-analcime, as he states (1936*a*, p. 136) that the phase formed could not yet be identified. However, from his experiments it can be seen that the temperature and pressure applied approximate the conditions characteristic of the formation of wairakite in nature. It is also noteworthy that the molecular ratio of the reactive components $CaO:Al_2O_3:SiO_2$ was 1:1:4, thus corresponding to the composition of wairakite. No data are given concerning pH which, according to Barrer (1948), can be as important in hydrothermal reactions as temperature or composition. Judging by the set of physical and chemical conditions used by Noll, one would expect that, unless the reaction time was too short or the concentration of CaO too low, he succeeded in his synthesis of calcium-analcime. But it should be noted that he used the same set of conditions and material for his successful synthesis of analcime except that $Ca(OH)_2$ was, of course, replaced by NaOH. The importance of Noll's attempt to synthesize calcium-analcime by hydrothermal crystallization is much enhanced by the discovery of wairakite. Therefore, the suggestion is made that this synthesis should be attempted anew.

Relationship between wairakite and analcime.

It is obvious that wairakite ($CaO.Al_2O_3.4SiO_2.2H_2O$) and analcime ($Na_2O.Al_2O_3.4SiO_2.2H_2O$) have analogous formulas. This analogy raises the question whether and to what extent an isomorphous substitution takes place between the two. The possible existence of such an isomorphous series is examined by means of a triangular diagram (fig. 5). It shows the variation in content of soda, lime, and potash of 30 analcimes in relation to wairakite. In discussing this relationship the present writer is aware of the probable differences in the temperature of

formation of the specimens taken into consideration. The diagram brings out clearly that:

1. The extent of isomorphous substitution between analcime and wairakite is very limited, with only few scattered intermediate members.
2. Most of the points, 18 in number, are clustered near the Na_2O vertex.
3. The tendency for soda being substituted by lime and potash is restricted to the field between 50 and 100 % Na_2O.

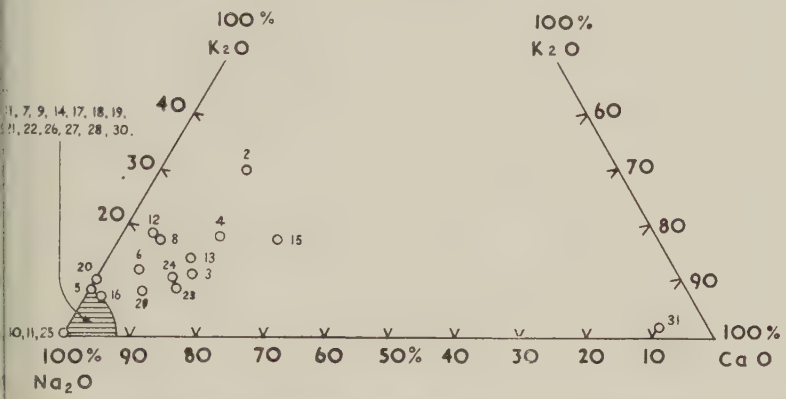


FIG. 5. Plot of chemical analyses of analcime (nos. 1–30) and wairakite (no. 31), showing lack of intermediate members.

References to analyses in fig. 5.

1. Morcinov (Kašpar, 1939). [M.A. **10**–35.]
2, 3, 4. Montana (Larsen and Buie, 1938). [M.A. **7**–448.]
5, 6. Arizona (Ross, 1928).
7. Loch Borolan (Stewart, 1941).
8. Oregon (Hewett et al., 1928). [M.A. **4**–324.]
9. Foya (Klein, 1897).
0. Låven (new analysis).
1. Kyogle (Hodge-Smith, 1929). [M.A. **4**–323.]
2. Texas (Lonsdale, 1928). [M.A. **4**–96.]
3. Etna (Dana, Min., 1892, p. 597).
4, 15. Blagodatsk (ibid.).
6. Wiesenthal (ibid.).
7. Fassathal (ibid.).
8. Kuchelbad (ibid.).
9. Mte. Catini (ibid.).
20. Heldburg (ibid.).
21. Los Islands (Roques, 1947). [M.A. **10**-294.]
22. Eritrea (Morgante, 1945). [M.A. **11**-292.]
23, 24. Cyclopean Is. (Grassi-Cristaldi and Scafile, 1929). [M.A. **5**–83.]
25. Faeroe Is. (Tiselius, 1935). [M.A. **6**–524.]
26. Bohemia (Kratochvíl, 1933). [M.A. **6**–129.]
27. Hungary (Reichert and Erdélyi, 1935). [M.A. **6**–130.]
28. Timan (Zeberg, 1915). [M.A. **2**–58].
29. Caucasus (Smirnov, 1924). [M.A. **2**–527.]
30. Cyclopean Is. (Di Franco, 1926). [M.A. **4**–375.]
31. Wairakite (new analysis).

Thus, it can be concluded that, unless the intermediate members are stable only under conditions which are not common in nature, analcime and wairakite are isomorphously not related, though the atomic radii Na (0·98) and Ca (1·06) are approximately equal. The difference in valency and ionic charge appears to deter isomorphic replacement of analcime and wairakite.

However, isomorphous substitution of analcime and wairakite depends greatly on similarity of the crystal structure of these two minerals. A slight departure from the analcime structure is shown by wairakite according to the results of Dr. Coombs' X-ray investigation. If this structural difference is significant then analcime and wairakite can hardly be expected to form an isomorphous series at atmospheric temperatures.

Acknowledgements.—I acknowledge with thanks the assistance given by Mr. J. A. Ritchie, Dominion Laboratory, Wellington, in analysing wairakite, and analcime from Låven, and for his dehydration data, and by Mr. N. Wells of the Soil Bureau, Wellington, for a preliminary X-ray powder examination. I also thank the Ministry of Works, Wellington, for the drilling cores and samples of ejected rocks, and data concerning the temperatures measured in the drill holes at various depths.

References.

Barrer (R. M.), 1950. Ion-exchange and ion-sieve processes in crystalline zeolites. Journ. Chem. Soc. London, pp. 2342–2350. [M.A. **11**–291.]

Klein (C.), 1897. Über Leucit und Analcim und ihre gegenseitigen Beziehungen. Sitzungsber. Akad. Wiss. Berlin, vol. 15, p. 290.

Noll (W.), 1936*a*. Synthese von Montmorilloniten. Chemie der Erde, vol. 10, pp. 129–153. [M.A. **6**–353.]

—— 1936*b*. Über die Bildungbedingungen von Kaolin, Montmorillonit, Sericit, Pyrophyllit und Analcim. Min. Petr. Mitt., vol. 48, pp. 210–247. [M.A. **7**–96.]

Ross (C. S.), 1928. Sedimentary analcite. Amer. Min., vol. 13, pp. 195–197. [M.A. **4**–128.]

Steiner (A.), 1953. Hydrothermal rock alteration at Wairakei, New Zealand. Econ. Geol., vol. 48, pp. 1–13.

Stewart (F. H.), 1941. On sulphatic cancrinite and analcime (eudnophite) from Loch Borolan, Assynt. Min. Mag., vol. 26, pp. 1–8.

Winchell (A. N.), 1925. A new theory of the composition of the zeolites. Part I. Amer. Min., vol. 10, pp. 88–97. [M.A. **3**–13.]

X-ray observations on wairakite and non-cubic analcime.

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[Taken as read March 24, 1955.]

Introduction.

MR. A. STEINER has kindly invited the present writer to study by X-ray methods the new mineral wairakite described by him in the preceding pages. The material provided includes an incomplete octahedron 15 mm. across with small modifying icositetrahedron-like faces, and some smaller partial icositetrahedra. Faces are dull and give diffuse reflections on the optical goniometer, but, by attaching small pieces of glass cover-slip to improve the reflections, interfacial angles approximating to those of the cubic forms {111} and {211} were measured. As pointed out by Mr. Steiner, however, the mineral is birefringent, biaxial, and finely twinned. A preliminary small-diameter X-ray powder photograph taken by Mr. N. Wells of the Soil Bureau, Wellington, showed an apparently cubic, analcime-like pattern (personal communication).

Powder data.

X-ray photographs on a 19-cm.-diameter camera were taken of wairakite; birefringent analcime from Låven, Norway (Brögger, 1890; Stewart, 1941), provided by Mr. Steiner; birefringent analcime in a steam cavity in basalt from Flinders, Australia; and synthetic analcime provided by Professor R. M. Barrer. Doubling of many lines in the cases of wairakite and Låven analcime clearly indicate measurable departures from cubic symmetry (fig. 1 and table I) although the multiple lines are so closely spaced that they would probably not be resolved on a small-diameter camera or with thick specimen rods. A general structural similarity with analcime is confirmed.

In the wairakite pattern, reflections corresponding to the 400 and 800 reflections of analcime are doubled, indicating a cell with maximum and minimum dimensions of about 13·68 Å. and 13·56 Å. This represents a slight collapse compared with cubic analcime, in which a = 13·7 Å.,

and is presumably a result of the replacement of Na atoms by only half the number of Ca atoms.

TABLE I. X-ray powder data for wairakite and analcime. (Camera 19 cm. diameter, Cu-$K\alpha$ radiation.)

	Analcime, Flinders.		Wairakite.		Analcime, Låven.	
*hkl.**	Int.†	*d* Å.	Int.†	*d* Å.	Int.†	*d* Å.
(200)	< 1	6·87	4	6·85	2	6·88
211	8	5·61	8	5·57	8	5·61
220	4	4·86	4	4·84	4B	4·85
321	2	3·67	3	3·64	3B	3·64–3·67
400	10	3·43	6 10	3·42 3·39	10	3·43
(411,330)	—		< 1B	3·21	< 1	3·24
420	—		1B	3·04–3·06	2 < 1	3·08 3·06
332	8	2·925	5 3	2·909 2·897	7 3	2·929 2·896
422	2	2·801	1 1	2·783 2·770	2 1	2·804 2·779
431(510)	5	2·693	4 1	2·680 2·67	4 2	2·696 2·673
521	5	2·505	< 1 4	2·50 2·489	5	2·506
440	3	2·426	3	2·418	2	2·434
—	—			—	2	2·412
(530,433)	—		< 1B	2·35	< 1B	2·36
(600,442)	—		1B	2·26–2·28	1	2·290
611,532	4	2·226	4	2·215	3B	2·217–2·229
620	< 1	2·168	< 1 1	2·17 2·147	1	2·170
541	< 1	2·115	1 < 1	2·115 2·095	1 < 1	2·125 2·10
631	1	2·022	2	1·996	2B	2·015
543(550,710)	< 1	1·940	< 1B	1·93	< 1B	1·94
640	5	1·903	3B	1·886–1·895	3 3	1·906 1·892
—	—		1	1·867	—	
633,721,552	4	1·867	3	1·857	4B	1·869
—	—		1	1·844	—	
642	< 1	1·833	< 1B	1·822	—	
732,651	6	1·743	4B	1·722–1·732	5B	1·744–1·734
800	3	1·716	< 1 < 1	1·708 1·696	4	1·713
741(811,554)	4	1·689	2B	1·680	2 2	1·692 1·679
820(644)	1	1·664	< 1B	1·66	2	1·663
822,660	2	1·618	1B	1·612	2	1·621
831,743(750)	3	1·596	< 1 2	1·595 1·586	2B	1·596–1·585
842	2	1·498	1	1·487	1	1·500

TABLE I (*contd.*)

*hkl.**	Analcime, Flinders. Int.†	*d* Å.	Wairakite. Int.†	*d* Å.	Analcime, Låven. Int.†	*d* Å.
761,921,655 ...	2	1·480	1B	1·465	2	1·480
664 ...	1	1·463		—		—
754,851(930) ...	1	1·447	< 1B	1·437	1	1·449
932,763 ...	4	1·415	2B	1·407	3B	1·416
941,853(770) ...	< 1	1·386		—	1	1·390
860(10.0.0) ...	1	1·372		—	1	1·375
10.1.1,772 ...	4	$1·358_6$	1 1	1·354 1·343	3B	1·359
10.3.1,952,763 ...	1	1·308		—	2	1·309
871(855,774) ...	2	$1·284_9$		—	1	1·288
—	—			—	1	1·277
10.3.3,961 ...	2	$1·263_2$		—	1	1·266
963, &c.	3	$1·222_0$	2B	1·215	2B	1·224
—	—			—	1	1·214
677, &c.	1	$1·185_1$		—	1B	1·187
11.4.1,875 ...	1	$1·167_9$		—	< 1B	1·169
10.5.5, &c. ...	1	$1·120_2$		—	< 1B	1·122

* Indices in brackets are for cubic analcime reflections extinguished in the space group *Ia3d* inferred for the strictly cubic modification.

† Relative intensities estimated by eye in each case. B = Broad reflection, unresolved group.

In addition to the doubling of many lines, the wairakite powder pattern differs from that of typical analcime in the presence of additional reflections. For example, 200 and 411,330 are extinguished in the space group *Ia3d* to which cubic analcime appears to belong (discussed in next section), but corresponding lines occur with wairakite, 200 (6·85 Å.) in particular being relatively strong.

POLYMORPHISM OF ANALCIME.

Optical anomalies in analcime including fine twinning of birefringent units have been frequently reported, as discussed by Stewart (1941). Powder patterns of two analcimes showing such effects have been studied in comparison with the wairakite pattern. That of analcime from Låven, southern Norway, is particularly interesting. Brögger (1890, pp. 565–566) described this mineral and reported lamellar twinning parallel to the cubic cleavages and to a less extent parallel to the dodecahedral directions. The mineral was usually biaxial, but occasionally uniaxial and some parts were isotropic. A new partial analysis by the Dominion Laboratory (Steiner, 1955) reveals only traces of K and Ca. The optical anomalies are therefore not chemically controlled.

The Låven specimen available for the present work is optically negative, uniaxial or nearly so, and it shows very fine blotchy twinning. In the powder pattern (fig. 1*c*) most of the normal analcime lines are

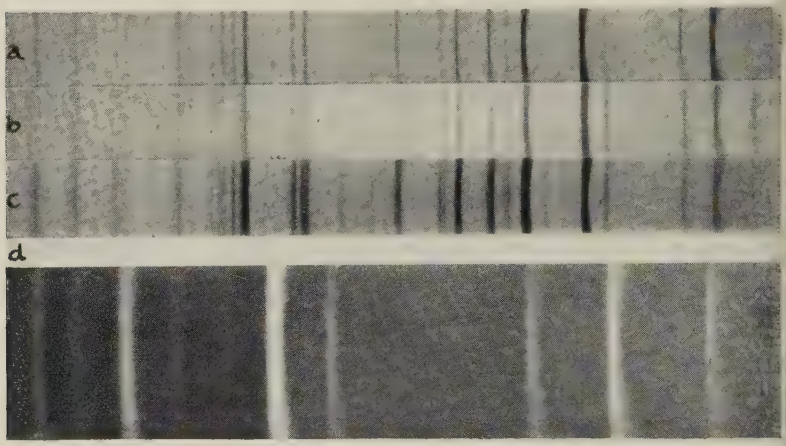

Fig. 1. X-ray powder photographs (lower θ region) of analcime and wairakite. Cu-$K\alpha$ radiation, Ni filter, camera 19 cm. diameter.

a, Analcime, Flinders, Australia. *b*, Wairakite, Wairakei, New Zealand. *c*, Analcime, Låven, Norway. *d*, Wairakite, enlargement of portion of the photograph (*b*) showing doubling of 400 (the strongest) and other reflections.

broadened or represented by resolved multiple groups, a notable exception being those of the form *h*00. This suggests that the cubic analcime structure has been distorted to trigonal or near-trigonal symmetry, one or other of the four cubic triads having become the only triad by change of length relative to the others, the *h*00 planes of the cube consequently having become rhombohedral planes. Each reflection or group of reflections in the Låven analcime pattern can therefore be allotted provisional indices based on a non-primitive body-centred rhombohedral cell by direct analogy with the corresponding lines in the pattern of cubic analcime. Thus cubic 440 is represented by two lines in the Låven analcime pattern, and these can be given the provisional rhombohedral indices 440 and $44\bar{0}$. This leads to two possible sets of lattice constants, but by consideration of observed and calculated spacings for other clearly resolved lines, one of these can be discarded and the pattern indexed in terms of a body-centred rhombohedral cell having a 13·71 Å., α 90° 31′. The corresponding primitive cell has the constants a 11·91 Å., α 109° 42½′, but the non-primitive form is the more useful for showing

the relationship to cubic analcime for which a 13·64–13·75 Å. according to various authors (e.g. Gruner, 1928 *a*, *b*; Taylor, 1930; Lyons, 1944). Data for critical indexed reflections are set out below (table II).

TABLE II. Calculated and measured lattice spacings for Låven analcime.

(hkl)*	d_{hkl}calc.	d_{hkl}obs.	Int.
400	3·427 Å.	3·428 Å.	10
$3\bar{3}2$	2·933	2·929	7
$33\bar{2}$	2·926		
332	2·897	2·896	3
$42\bar{2}$	2·810	2·804	2
$42\bar{2}$	2·802		
422	2·777	2·779	1
$4\bar{4}0$	2·434	2·434	2
440	2·412	2·412	2
640	1·908	1·906	3
$6\bar{4}0$	1·893	1·892	3
800	1·713	1·713	4

* hkl indices for body-centred rhombohedral cell.

Birefringent analcime from Flinders, Victoria, Australia, is biaxial with variable optic axial angle. Determinations were made with the range $2V_\alpha$ 45–120°, but the majority of fragments observed gave $2V_\alpha$ 68–85°. The mineral being biaxial, the true symmetry can presumably be no higher than orthorhombic. Nevertheless the powder pattern consists of thin sharp lines with spacings consistent with cubic symmetry and a body-centred unit cell a 13·72±0·01 Å. A significant feature, however, is the presence of a weak line d 6·87 Å., corresponding to 200. This does not appear to have been present in previously recorded analcime powder patterns (e.g. Taylor, 1930; Konta, 1953), nor is it present in that of the synthetic analcime provided by Professor R. M. Barrer. This latter sample consists of crystals with a maximum diameter of 0·05 mm. Double refraction effects were not detected. It is interesting to note that Konta states that his material is strictly isotropic.

A 200 reflection is incompatible with the space group $Ia3d$ (O_h^{10}) which has as a requirement for reflections hhl, that $2h+l = 4n$, and for $0kl$ that k, $l = 2n$. This space group has been accepted for analcime by most workers (Gruner, 1928*a*; Hartwig, 1928; Jaeger, 1929; Taylor, 1930). On the other hand, Gruner (1928*b*) suggested that O_h^3 ($Im3m$) was more likely on account of the presence in oscillation photographs

of certain rather doubtfully indexed reflections, and Schiebold (1930) considered the mineral to be tetragonal, space group D_{4h}^{20} ($I4_1/acd$). Taylor (1930, pp. 12–13) pointed out that the structure he determined for analcime (1930, 1938) is based on the cubic space group $Ia3d$ with Si and Al ions occupying equivalent positions. Optical anomalies suggested that the mineral is only pseudo-cubic which would require non-equivalence (ordering) of the Si and Al atoms. The detailed arrangement has been further discussed by Beattie (1954).

In non-cubic sub-groups derived from $Ia3d$ many limitations on possible reflections are removed. Thus reflections in positions corresponding to 200 and 411,330 and many other $Ia3d$ extinctions are well represented in the wairakite and Låven analcime patterns. The presence of anomalous reflections in the patterns of Flinders and other birefringent analcimes does not mean that a disordered, strictly cubic, isotropic modification of analcime does not exist; in fact, the synthetic analcime appears to be of this type. It is suggested that weak reflections of the type hhl where $2h+l\neq 4n$, may appear when the true symmetry is non-cubic as indicated by the optical properties, even though the cell dimensions have not departed detectably from cubic requirements.

In the past the birefringence of analcime has been ascribed to loss of water (e.g. Náray-Szabó, 1938) although analyses at ordinary temperatures appear to show approximately the theoretical amount, or to strain during or after crystallization (Bannister, 1931; Stewart, 1941). Although Klein (1897, p. 350) found that the birefringence increased when analcime was heated in a dry atmosphere, the mineral usually became isotropic when heated to 250° in the presence of water vapour, becoming birefringent again on cooling.

The data appear to be consistent with an inversion process from a strictly cubic form existing in the presence of water vapour at moderately elevated temperatures to one or more forms of lower symmetry stable at ordinary temperatures. Evidence will be presented for a somewhat similar relationship in wairakite, and Wyart (1937) has clearly shown by X-ray methods the progressive and reversible transformation of a low-temperature tetragonal modification of the analogous mineral leucite to the cubic form at 625° C. The fact that analcime is shown to exist at ordinary temperatures with varying departures from cubic symmetry suggests that in its case the transformations tend to be more sluggish or complicated so that we see the products in various arrested states. Barrer, Baynham, and McCallum (1953) have recently discussed polymorphism among analcime-like structures with special reference to

two modifications of synthetic Rb-analcime, both tetragonal. The sluggishness of the transition of these suggested a reconstructive process such as an order-disorder relationship of Si and Al ions rather than a displacive transformation as in leucite.

Tentatively, the following modifications of analcime may be recognized:

(i) Strictly cubic and isotropic, space group *Ia3d*. The synthetic specimen, hydrothermally prepared, appears to belong here.

(ii) Birefringent and biaxial, departures from cubic lattice dimensions not detectable although anomalous X-ray reflections may appear, e.g. Flinders analcime.

(iii) Trigonal or nearly trigonal with rhombohedral angle approximately $90\frac{1}{2}°$, e.g. Låven analcime. Biaxial specimens from the same locality must be of lower symmetry.

The relation of these polymorphs to the high-pressure transition briefly reported by Morey (1953, p. 69) remains to be elucidated.

A systematic study of natural and synthetic analcimes in relation to their thermal history is beyond the scope of the present work. It is conceivable, however, that such a project could yield information of use in the lower temperature ranges of geothermometry, with applications in problems of diagenesis and incipient metamorphism as well as vein and amygdale deposition.

Twinning, optical orientation, and cell dimensions of wairakite.

An orientated thin section was cut through an octahedron perpendicularly to one of the tetrads. As in most grains of wairakite as seen between crossed nicols, the most obvious characteristic is the presence of fine, discontinuous lamellar twinning with conspicuous sets at right angles to each other. These are found to be parallel to (pseudo-)cubic {110} planes. Universal-stage examination reveals six sets of such dodecahedral twin lamellae in all. The extinction directions bisect, at least approximately, the angles between pairs of mutually perpendicular twin lamellae and hence remain closely parallel to the tetrads of the octahedron. The orientated section shows a very distinct cleavage parallel to the {100} directions as is the case with analcime. Oscillation photographs of twinned aggregates detached from the orientated section confirm that there is a repeat distance of about 13·6 A. throughout, essentially parallel to each of the tetrads of the octahedron.

Twinning as here described recalls the secondary twinning so readily produced by inversion processes in anorthoclase, leucite, and other minerals. The indications are strong that wairakite crystallized in strictly cubic octahedra and icositetrahedra and on cooling inverted to a modification shown to be monoclinic. Any one of the (equivalent) a, b, and c cell-edges of the original cubic form could, in different parts of the crystal, become either a, b, or c (non-equivalent) of the lower-symmetry modification, giving rise to the complex twinning. In each case the new cell-edges remain essentially parallel to the cell-edges of the originally cubic modification. The twinning largely compensates for the strains caused by differential contraction along the different cell-edges, and the external apparently cubic morphology is retained, although with dulled faces.

Weissenberg photographs were taken about a, b, and c axes of a small fragment from the orientated section. The nature of the twinning makes interpretation complex, but on the basis of the fact that the larger part of the fragment has a single optical orientation, the following dimensions and orientation were determined. They are based on a body-centred cell to emphasize the relationship with analcime: a (near optical β) $13{\cdot}69 \pm 0{\cdot}02$, b (optical α) 13·68, c (near optical γ) 13·56 Å., β 90·5°. $8(CaAl_2Si_4O_{12}.2H_2O)$ per unit cell.

In regions showing two mutually perpendicular sets of twin lamellae, the short edge c is parallel to their direction of intersection and the lamellae are twinned on (110) and $(1\bar{1}0)$. The cell is seen to be pseudo-cubic and even more nearly pseudo-tetragonal.

A condition for reflections hkl is that $h+k+l = 2n$. In zero-layer Weissenberg photographs, very weak reflections were observed in positions closely corresponding to $h0l$ where h, l are odd. However, in each case these were satisfactorily accounted for as $0kl$ reflections from that part of the crystal in twinned orientation across (110), and it is highly probable that a condition for reflections $h0l$ is that $h = 2n$. In this case the space-group symbol for the chosen setting of wairakite is Ia or $I2/a$.

It is significant that reflections that do not accord with the extinction requirements for the cubic space group $Ia3d$ tend to be weak or very weak. This is compatible with the view that the wairakite structure is derived from a cubic analcime-like structure by a non-reconstructive type of phase transformation. The fact that the observations were made on ejected fragments, presumably quickly cooled from near the crystallization temperature, suggests that the change may be of the rapid,

displacive type as in leucite, but a decision on this point, as on the inversion hypothesis as a whole, must await experimental work performed at appropriate temperatures and pressures of water vapour.

Structure of wairakite.

Beattie (1954) points out that although in terms of Taylor's structure for analcime there are 24 possible Na positions, each with an environment of 4 oxygen atoms associated with 2(Si,Al), only 16 of these groups can contain simultaneously one Al atom as well as Si. For valency reasons these are presumably the 16 sites occupied by the 16 Na ions in the unit cell. Beattie further suggested the possibility of an arrangement in which eight positions would have an environment of 4 oxygens associated with 2Al, and 16 positions with 4 oxygens and 2Si. Divalent calcium, as in wairakite, should favour the former of these last two types of site. A different and more specialized distribution of Si and Al atoms is thus implied as compared with that of Na-analcime. On this basis one might explain the failure to obtain pure Ca-analcime (wairakite) by base-exchange experiments with Na-analcime.

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References.

Bannister (F. A.), 1931. The distinction of analcime from leucite in rocks by X-ray methods. Min. Mag., vol. 22, pp. 469–476.

Barrer (R. M.), Baynham (J. W.), and McCallum (N.), 1953. Hydrothermal chemistry of silicates, Part V. Compounds structurally related to analcite. Journ. Chem. Soc. London, pp. 4035–4041. [M.A. **12**–309.]

Beattie (I. R.), 1954. The structure of analcite and ion-exchanged forms of analcite. Acta Cryst., vol. 7, pp. 357–359. [M.A. **12**–484.]

Brögger (W. C.), 1890. Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit- und Nephelinsyenite. Zeits. Krist., vol. 16, 658 pp.

Gruner (J. W.), 1928*a*. Die Struktur des Analcims. I. Die Raumgruppe. Zeits. Krist., vol. 68, pp. 363–378. [M.A. **4**–34.]

—— 1928*b*. The use of the oscillation method in determining the structure of analcite. Amer. Min., vol. 13, pp. 174–194. [M.A. **3**–530.]

Hartwig (W.), 1928. Über die Struktur von Analcim. Centr. Min. Abt. A, p. 380. [M.A. **4**–369.]

JAEGER (F. M.), 1929. On the constitution and structure of ultramarine. Trans. Faraday Soc., vol. 25, pp. 320–345. [M.A. **4**–463.]

KLEIN (C.), 1897. Über Leucit und Analcim und ihre gegenseitigen Beziehungen. Sitzungsber. Akad. Wiss. Berlin, pp. 290–354.

KONTA (J.), 1953. Hydrothermaler Analcim der kupferhaltigen Schichtenfolge des Perms aus dem Vorland des Riesengebirges (Horní Kalná) und seine Bedeutung für die Herkunft des Kupfers. Geologie, vol. 2, pp. 237–252.

LYONS (J. B.), 1944. Igneous rocks of the northern Big Belt range, Montana. Bull. Geol. Soc. Amer., vol. 55, pp. 445–472. [M.A. **9**–278.]

MOREY (G. W.), 1953. Annual report of the director of the Geophysical Laboratory. Carnegie Inst. Washington, Year Book, no. 52 (for 1952–1953), pp. 39–96.

NÁRAY-SZABÓ (S. v.), 1938. Die Struktur des Pollucits $CsAlSi_2O_6.xH_2O$. Zeits. Krist., vol. 99, pp. 277–282. [M.A. **7**–238.]

SCHIEBOLD (E.), 1930. Zur Struktur von Nephelin und Analcim. Die Naturwissenschaften, vol. 18, pp. 705–706. [M.A. **4**–368.]

STEINER (A.), 1955. Wairakite, the analogue of analcime, a new zeolite mineral. Min. Mag., vol. 30, pp. 691–698.

STEWART (F. H.), 1941. On sulphatic cancrinite and analcime (eudnophite) from Loch Borolan, Assynt. Min. Mag., vol. 26, pp. 1–8.

TAYLOR (W. H.), 1930. The structure of analcite ($NaAlSi_2O_6\ H_2O$). Zeits. Krist., vol. 74, pp. 1–19. [M.A. **4**–369.]

—— 1938. Note on the structures of analcite and pollucite. Zeits. Krist., vol. 99, pp. 283–290. [M.A. **7**–238.]

WYART (J.), 1937. Sur un cas de polymorphisme par passage progressif d'un arrangement cristallin à un autre plus symétrique, observé sur la leucite. Compt. Rend. Acad. Sci. Paris, vol. 205, pp. 1077–1079. [M.A. **7**–278.]

Gedrite from Glen Urquhart, Inverness-shire.

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[Read January 27, 1955.]

THIS note describes a hydrous gedrite from Glen Urquhart for which the presence of an appreciable excess of oxygen atoms over the normal 96 per unit cell has been established. This is associated with an approximately equal deficiency of cations. The type of isomorphous replacement here discussed is hitherto unrecorded in the amphibole group.

Field occurrence.

The hydrous gedrite occurs as an almost monomineralic rock, gedritite, which was found at only one place in Glen Urquhart. This is a road cutting at the junction of the Milton-Kiltarlity road with a side road to the Gartally farms, a quarter of a mile from Milton. This must be the locality described by Heddle[1] as 'near the Free Church of Millton', where he obtained hydrous anthophyllite and other minerals.

The gedritite carries a grey or iron-stained crust on which radiating fans of the amphibole with prisms up to 6 cm. in length appear. On fresh surfaces the prisms have the typical clove-brown colour from which anthophyllite gets its name. Occasionally the rock holds giant hornblendes; one such crystal measures $11 \times 7 \times 4$ cm. Accessory hydrobiotite, talc, rutile, and serpentine are present in the rock.

The occurrence is in a zoned hydrothermal body in a large serpentinite mass. The gedritite zone lies between a kyanite-hydrobiotite-rock and the serpentinite. It probably owes its high alumina content to the former and its high water content to the latter rock. A full discussion of the serpentinite mass and the zoned body will be given in later papers.

Physical and chemical data.

Careful separation by means of heavy liquids and an isodynamic separator removed the small amounts of hydrobiotite, talc, rutile, and

[1] M. F. Heddle, Min. Scotland, 1901, vol. 2, p. 40.

serpentine present in the rock. The resulting powder, of typical clove-brown colour, was found to contain no more than a trace of impurity, judged to be less than 1 %. Optical constants of the gedrite are:

Refractive indices.	Birefringence.	Optic axial angle.
α 1·611 β 1·620 γ 1·632 ±0·002	$\gamma-\alpha$ 0·021	$2V\gamma$ (measured) 85° $2V\gamma$ (calculated) 82

X-ray single-crystal and powder photographs were made on the gedrite. Pictures taken with oscillation about c provided a good measurement for that axis which agrees with the powder photographs results. Photographs of crystals oscillated normal to c showed that the needles separated for study are to some extent fibred parallel to c, and were thus unsuitable for measuring the a and b cell-sides. From powder pattern spacings (Fe-$K\alpha$ radiation) on a 19-cm. camera the following cell dimensions were obtained: a 18·52±0·04, b 17·79±0·04, c 5·31±0·01 Å. When compared with the figures given by J. C. Rabbitt[1] these are found to lie within the limits of variation of the anthophyllite group and are not extreme. X-ray powder spacings for Fe-$K\alpha$ radiation appear in table I.

Table I. X-ray powder spacings of gedrite from Glen Urquhart, Inverness-shire. Taken on a 19-cm.-radius camera with Fe-$K\alpha$ radiation.

$\sin^2\theta$.	d(Å.).	Int.	Indices.	$\sin^2\theta$.	d(Å.).	Int.	Indices.
0·0116	8·99	m	—	0·2036	2·14	w	(502)
0·0138	8·28	s3	(210)	0·2085	2·12	w	(561)
0·0182	7·19	m	—	0·2211	2·06	vw	(840)
0·0475	4·45	w	(040)	0·2391	1·98	vw	(751)
0·0555	4·11	w	(420)	0·2767	1·84	vw	(860)
0·0628	3·87	vw	(131)	0·3145	1·73	vw	—
0·0713	3·63	m	(321)	0·3613	1·61	vw	—
0·0740	3·56	w	—	0·3936	1·54	vw	(12.0.0)
0·0846	3·32	w	(331)	0·4137	1·51	m	(0.12.0)
0·0909	3·21	s2	(440)	0·4654	1·42	vw	(11.6.1)
0·1014	3·04	s1	(610)	0·4712	1·41	w	—
0·1142	2·87	m	—	0·5330	1·33	vw	—
0·1189	2·81	m	—	0·7145	1·15	vw	—
0·1250	2·74	m	(630)	0·8702	1·04	vw	—
0·0325	2·66	m	—	0·8859	1·03	vw	(16.8.0)
0·1434	2·56	m	(202)	0·8947	1·02	vw	—
0·1462	2·53	m	—	0·9268	1·01	vw	—
0·1514	2·49	m	(451)	0·9437	1·00	vw	—
0·1756	2·31	w	(551)				

The indices have been assigned by comparison of $\sin^2\theta$ values with those of K. Johansson (Zeits. Krist., 1930, vol. 73, p. 31). [M.A. **4**–356.]

[1] J. C. Rabbitt, Amer. Min., 1948, vol. 33, p. 263. [M.A. **10**–416.]

The density was measured on coarse fragments immersed in methylene iodide diluted with benzene. Since no inclusions of iron ore or other heavy impurity are present, the liquid taken as correct is that in which one crystal floated in mid-liquid after centrifuging, the rest having floated to the surface. Since the expected inclusions, especially air in cleavages and cracks, will lower density, the purest crystal is the one with the highest density. This proved to be $3{\cdot}122 \pm 0{\cdot}010$ at 20° C., referred to water at 4° C.; when corrected for 0·42 % of water lost at 110° C., assumed to be adsorbed water, this becomes $3{\cdot}150 \pm 0{\cdot}010$.

TABLE II. Chemical analyses and empirical unit-cell contents of gedrite from Glen Urquhart, Inverness-shire.

		1.	2.			1a.	1b.
SiO_2	...	43·03	47·72	Si	...	$23{\cdot}97 \pm 0{\cdot}25$	26·28
Al_2O_3	...	26·65	3·84	Al	...	$17{\cdot}50 \pm 0{\cdot}22$	19·18
TiO_2	...	0·75	0·18	Ti	...	$0{\cdot}30 \pm 0{\cdot}02$	0·34
Fe_2O_3	...	0·66	—	Fe'''	...	$0{\cdot}28 \pm 0{\cdot}06$	0·30
FeO	...	11·69	5·74	Fe''	...	$5{\cdot}44 \pm 0{\cdot}06$	5·98
MnO	...	0·13	0·16	Mn	...	$0{\cdot}06 \pm 0{\cdot}003$	0·07
MgO	...	9·59	28·75	Mg	...	$7{\cdot}96 \pm 0{\cdot}14$	8·72
CaO	...	1·28	5·64	Ca	...	$0{\cdot}76 \pm 0{\cdot}04$	0·84
Na_2O	...	0·48	0·26	Na	...	$0{\cdot}52 \pm 0{\cdot}10$	0·57
K_2O	...	0·21	0·19	K	...	$0{\cdot}15 \pm 0{\cdot}04$	0·16
$H_2O+110°$ C.		4·72	7·65	O	...	83·57	94·42
$H_2O-110°$ C.		0·42		OH	...	12·43 ± 0·76	8·00
				H_2O	...	2·55	
		99·61	100·13				
$D_{obs.}$	...	3·122	2·81	total (O,OH,H_2O)		$98{\cdot}55 \pm 0{\cdot}81$	102·42
				total (cations)		$56{\cdot}95 \pm 0{\cdot}54$	62·44

1. Gedrite, Glen Urquhart (B.M. 1955,63). Part of the same specimen is in the Harker Collection, Department of Mineralogy and Petrology, Cambridge, (no. 76,306). G. H. Francis, analyst.
2. 'Hydrous anthophyllite', Glen Urquhart. M. F. Heddle, 1901, loc. cit., p. 41.
1a. Empirical unit-cell contents, from analysis 1, assuming all the H_2O+ is essential.
1b. Empirical unit-cell contents, from analysis 1, assuming the unit cell contains 8(OH) and all other water is adsorbed impurity.

A chemical analysis gave the results included in table II, and was supplemented by a spectrographic determination of the trace elements by Dr. S. R. Nockolds, which gave the following values (parts per million): Rb trace,[1] Cs nil, Tl nil, Sr trace, Ba 12, Ga 15, In nil, Sc 15, Yt 12, La trace, Zr 18, Sn trace, Pb trace, V 125, Cr 100, Mo trace, Co 17, Ni 22, F nil.

[1] Trace implies that the element is present, but below the limit of quantitative determination.

An analysis of 'hydrous-anthophyllite' originally given by M. F. Heddle[1] as from 'the Bay of Scourie' (Sutherland), has been quoted by A. Lacroix,[2] on the authority of a Dr. Wilson, as being from Glen Urquhart, together with a statement that it was the mineral analysed in Heddle's paper. Lacroix then showed from its optics that it was actinolite—disproving to his own satisfaction and Dana's[3] that Heddle's 'hydrous-anthophyllite' existed. It may be said that this examination of the wrong mineral from the wrong locality proves nothing. Heddle does record a hydrous anthophyllite from Milton, Glen Urquhart,[4] for which he records a composition quite distinct from the Scourie analysis: unfortunately this does not approach the composition now found for the gedrite. Much of the gedritite is now represented by pseudomorphs in talc and serpentine after gedrite. In one case a fine specimen with large radiating 'crystals' was found to be composed of pseudomorphous talc and serpentine only after the cutting of a thin section. It thus appears that Heddle analysed a pseudomorph after anthophyllite; this is supported by his analysis (table II, 2) which could be explained as a talc-serpentine mixture.

The true contents of the unit cell.

Assuming that all the water retained at 110° C. is an essential part of the mineral, the empirical unit-cell contents were calculated, together with approximate probable errors calculated by the method proposed by M. H. Hey;[5] the results, included in table II, col. 1*a*, are remarkable for the very high content of 98·5 (O,OH,H_2O), a figure quite outside the probable error of the observations.

Apart from a few specialized groups, such as the zeolites, scapolites, and ultramarines, previous work on silicates has always supported an integral sum of ($O+OH+F+Cl$), invariable within any one isomorphous group of silicates, and it seemed essential to exclude any other possibility before accepting the view that the Glen Urquhart gedrite does in fact contain nearly 99 oxygen atoms per unit cell instead of the 96 normal in the ortho-amphiboles.

[1] M. F. Heddle, Min. Mag., 1882, vol. 4, p. 213.

[2] A. Lacroix, Bull. Soc. Min. France, 1888, vol. 9, p. 7.

[3] E. S. Dana, Syst. Min., 6th edn., 1892, p. 384.

[4] M. F. Heddle, Min. Scotland, 1901, vol. 2, p. 40.

[5] M. H. Hey, Min. Mag., 1954, vol. 30, p. 481, assuming the following possible errors in the chemical analysis: SiO_2 0·3 %; Al_2O_3 and H_2O 0·2 %; MgO 0·15 %; total iron as Fe_2O_3, FeO, and Na_2O 0·10 %; TiO_2, CaO, and K_2O 0·05 %; MnO 0·01 %.

There are two other possibilities: the mineral might contain substantial amounts of impurities with a more close-packed structure and higher density, so that the observed density is too high through the presence of impurities; or part of the water lost above 110° C. might be adsorbed and not essential water. The first possibility may be ruled out by the thorough purification of the gedrite, which shows less than 1 % of impurities under the microscope; the second possibility has been investigated and shown to lead to an even higher empirical unit-cell content of oxygen.[1] If we assume that the gedrite has in fact the commonly accepted content of eight hydroxyl groups per unit cell, we can calculate that 2·76 % of the H_2O+ must be adsorbed impurity; correction of the density for this gives a value of 3·357, leading to 102·4 (O,OH) per unit cell (table II, col. 1b). Clearly this interpretation must be rejected.

It is quite clear that in the Glen Urquhart gedrite we have a very unusual amphibole; as the empirical unit-cell contents in table II, column 1a, show, the total cations per unit cell are notably low, and the total oxygen ($O+OH+H_2O$) is high by approximately the same amount. These appear to be established facts, but their interpretation must be a matter of speculation, pending a detailed structural study of the mineral. It can be interpreted as a replacement of 8(Si,Mg) by 16Al, the remaining 1·5 Al replacing Mg, and the tetrahedral positions in the $(Si,Al)_4O_{11}$ chains being completely filled; in this case there must be a deficit of nearly 3 cations in the octahedral positions, balanced by a replacement of O by OH to the extent of over four atoms per unit cell (12·4 OH instead of the normal 8). The excess of 2·5 oxygen atoms per unit cell could be water molecules accommodated either in the vacant octahedral positions left by the missing 3 cations, or in adjacent 'A' positions –the lattice positions normally vacant in anthophyllite, but occupied by Na and Ca in many hornblendes. Alternatively, it could be assumed that there are vacancies in the tetrahedral lattice positions of the Si_4O_{11} chains (the $SiO_4 \rightleftharpoons (OH)_4$ replacement noted in the hydrogarnets and advocated by D. McConnell[2] in several other silicates); but

[1] In fact, to regard H_2O+ as an impurity, rather than essential, will almost invariably increase the apparent oxygen atoms per unit cell in any mineral. More specifically, it will do so whenever the percentage of oxygen in the mineral is greater than $88/(D+1)$, where D is the density of the mineral. Or, if molecular ratios are calculated in the usual way by division of the percentages of the several oxides by their molecular weights, and an oxygen ratio R_o is derived from the molecular ratios, interpretation of H_2O+ as an impurity will increase the apparent oxygen atoms per unit cell if $R_o > 5{\cdot}51/(D+1)$.

[2] D. McConnell, Amer. Min., 1950, vol. 35, p. 166 [M.A. **11**–220]; Clay Minerals Bull., 1951, vol. 1, p. 179.

in that case it would not be so easy to understand why the excess of oxygen atoms per unit cell should be approximately equal to the deficit of cations. When more examples of this oxygen excess come to light regularities may become apparent, but at present any further speculation seems pointless.

Progressive heating experiments.

In the hope of obtaining additional evidence in confirmation of the view that approximately 1·6 % of the water in the Glen Urquhart gedrite is accommodated in interstitial lattice positions, normally unoccupied in anthophyllite, the loss of weight of powdered samples was determined at a series of temperatures up to 1200° C. At temperatures of 500°, 700°, 800°, 900°, and 1000° C. parts of the samples were abstracted, their percentage weight of FeO determined, and their structure tested by means of powder photographs. These samples all possess the powder pattern of the unheated material, but this gets progressively weaker with increasing temperature. A powder photograph of material heated to 1100° C. shows inversion to pyroxene with some amorphous material. The powder photograph after heating to 1200° C. shows a sharper pyroxene pattern with scant remaining amorphous material.

Table III contains the calculated results of the progressive heating

Table III. Compositional changes on progressive heating of gedrite from Glen Urquhart.

Temp. ° C.	Fe‴.	OH.	O.	H_2O.	(O,OH, H_2O).	A.	B.	C.	D.	E.
100	0·28*	12·43	83·57	2·55	98·55	0·00	0·00	0·00	0·00	0·00
200	0·28	12·43	83·57	2·55	98·55	0·00	0·00	0·00	0·00	0·00
300	0·88	11·83	84·17	2·42	98·42	0·86	0·26	0·60	0·00	0·26
400	1·78	10·93	85·07	2·20	98·20	2·20	0·70	1·50	0·00	0·70
500	2·46*	9·55	86·13	2·10	97·78	3·72	1·54	2·18	0·64	0·90
550	2·48	9·03	86·40	1·80	97·20	4·80	2·60	2·20	1·20	1·40
600	2·53	8·43	86·69	1·25	96·37	6·60	4·36	2·25	1·76	2·60
650	2·63	7·83	87·04	0·28	95·15	9·16	6·80	2·35	2·26	4·54
680	2·77	7·59	87·25	—	94·84	9·44	7·46	2·49	2·35	5·10
700	2·93*	7·43	87·41	—	94·84	10·10	7·46	2·65	2·35	5·10
750	3·90	6·37	88·40	—	94·77	11·18	7·56	3·62	2·46	—
800	4·84*	3·49	90·32	—	93·81	14·04	9·48	4·56	4·38	—
850	5·23	0·99	91·76	—	92·75	16·54	11·60	4·95	6·50	—
860	5·30	0·41	92·09	—	92·50	17·12	12·10	5·02	7·00	—
900	5·50*	0·19	92·30	—	92·49	17·34	12·12	5·22	7·02	—
950	5·68	0·09	92·40	—	92·49	17·44	12·00	5·40	7·02	—
1000	5·72*	0·00	92·50	—	92·50	17·54	12·12	5·44	7·02	—

1100 inverted to pyroxene.

* Direct values, all others depend on interpolation in the Fe‴ curve.

The temperature intervals at which weighings were made appear in the first column. In the second are figures for Fe''' per unit cell taken by difference from total iron; the intermediate values are interpolated in the Fe''' curve. The next four columns show OH, O, H_2O (in excess of 96) per unit cell and the sum of these. Clearly in this heating three processes are at work, each involving loss of H. They are:

Reaction 1, oxidation, $Fe''(OH) \rightarrow Fe'''O + H$.

,, 2, loss of hydroxyl water, $2(OH) \rightarrow O + H_2O$.

,, 3, dehydration (loss of interstitial water).

The losses of H atoms per unit cell for these reactions in combination

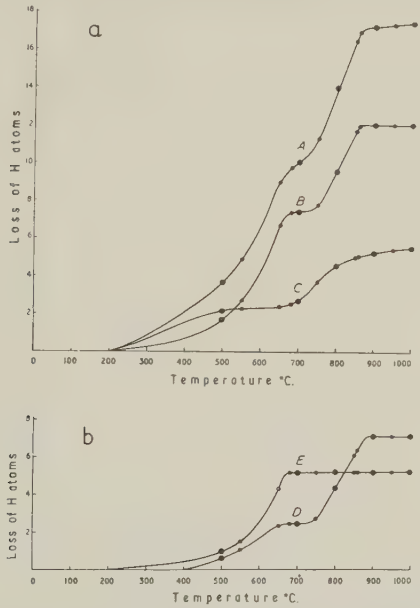

FIG. 1. Progressive heating curves: (*a*) determined, (*b*) assuming reaction 3 to have gone to completion just above 650° C. Curves A (reactions 1, 2, and 3), B (reactions 2 and 3), C (reaction 1), D (reaction 2), E (reaction 3) are taken from figures in the corresponding columns of table III. Larger dots correspond to direct determination of Fe''', small dots are interpolated in the Fe''' curve.

and separately are given in table III columns A–E and in the curves A–E of fig. 1, to which they correspond. Curve A represents the combined loss of H atoms by reactions 1, 2, and 3. It can loosely be referred to as 'water lost'. B is the loss of H atoms by reactions 2 and 3, that is by dehydration. C is the loss of H atoms by oxidation of ferrous to ferric iron (reaction 1). These three curves are directly determinable.

D and E represent reactions 2 and 3 respectively; in the absence of any direct evidence by which the division of the values of curve B into reactions 2 and 3 could be assessed, we may assume reaction 3 to have gone to completion just above 650° C. (see H_2O column, table III), and reaction 2 to have started before that.

It appears from this work that reaction 1 begins at quite a low temperature. It is quite marked by 500° C., but then the rate of oxidation appears to slow, though this may be only an apparent check. It may be that the more readily accessible outer parts of the grains have undergone oxidation by 500° C. and that further oxidation is checked until dehydration produces cracking of the grains. Several other possibilities could also be suggested.

Reaction 2 almost certainly starts before the loss of interstitial water is complete, probably about 400° C. There appears to be a check in this dehydration about 650°–700° C., followed by a rapid loss of the remaining water over the range 750°–870° C.

Reaction 3 is the loss of the interstitial water thought to be in the vacant octahedral positions left by the 3 missing cations, or in the adjacent 'A' positions. It starts at about 200° C. and goes on at an increasing rate; it is probably complete just above 650° C. (see above), the greater part of the loss taking place above 500° C.

This work supports the theoretical conclusion that loosely held water molecules exist in this structure additional to the expected 8(OH) per unit cell. It also demonstrates that complete dehydration of two types, $X_7Z_8O_{22}(OH)_2 \rightarrow X_7Z_8O_{24}$ (with oxidation of ferrous to ferric iron) and $X_7Z_8O_{22}(OH)_2 \rightarrow X_7Z_8O_{23}$ can be induced in this amphibole by heating, before its inversion to pyroxene. An examination of the physical properties of anthophyllites in relation to their varying chemical compositions will be presented in a later paper.

Acknowledgements.—My thanks are due to Professor C. E. Tilley for advice during the early part of this study, carried out at Cambridge University, also to Dr. S. R. Nockolds for the spectrographic determinations and to Dr. P. Gay for advice on the X-ray work. Whilst at Cambridge University I was supported by maintenance grants from the Ministry of Education and the Department of Scientific and Industrial Research, which are gratefully acknowledged. I have to thank Dr. M. H. Hey of the British Museum for much help and advice, and Messrs. D. I. Bothwell and K. C. Chaperlin, of the Museum, who carried out the progressive heating experiments.

The structural formula of a hydrous amphibole.

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[Read January 27, 1955.]

THE majority of amphiboles conform to the general structural formula $X_{2\text{-}3}Y_5Z_8O_{22}(OH,F,Cl)_2$, where X = Na, K, Ca, Y = Mg, Fe″, Mn, Al, Fe‴, Ti, and Z = Si, Al or Ti. Two X ions occupy the positions filled by Ca in the ideal tremolite structure; the additional X ions are assumed to occur in the 'A' sites which are vacant in tremolite.

For the amphiboles, therefore, the method most commonly adopted for deriving a formula from a chemical analysis is to assume that a total of 24 anions is present in the formula unit. In many published analyses, however, the amount of H_2O+ is seen to be greater than that required to make (OH,F,Cl) = 2, and it has been suggested (Hutton, 1940, and others) that extra hydrogen occurs as part of a water molecule or (OH) ion occupying some of the 'A' sites. This would imply an anion total greater than 24 and clearly cannot be demonstrated by a method of calculation which assumes 24 anions per formula unit. Moreover, if in fact the anion total does differ from 24 the calculation will yield incorrect results for the numbers of different cations. Thus, if the formula unit actually carries less than 24 anions, high values for the cation numbers will be obtained, from which it may be erroneously inferred that some Y ions are entering X positions, and the resulting high value for the total $(X+Y)$ may in some circumstances be taken as indicating occupation of the 'A' sites. This effect is exaggerated by the normal procedure of arbitrarily putting only enough Al and Ti into the Z positions to make the total number of ions there 8, the remainder of the Al and Ti being introduced into the Y group and possibly some Y ions being transferred to X positions. Again, in a case where some extra anions or water molecules are in the 'A' sites, calculation on the '24' basis not only fails to reveal the fact but gives erroneously low values for cation numbers.

Procedures for calculating structural formulae have been discussed critically and in detail by Hey (1939, 1954). It is clear that from an analysis only the relative proportions of ions are given, and in the absence of further data a formula unit may be derived from these only when an assumption is made about the numbers of one type of ion.

Hey pointed out that the numbers of the different ions in the unit cell can be determined without this assumption provided that the cell volume and the density are known with sufficient accuracy.

If the percentage of an oxide R_mO_n of molecular weight M is P, cell volume V Å.^{3}, and density $D(g./c.c.)$, then the number of R atoms in the cell is given by $(Pm/100M)\times(VD/1{\cdot}6603)$. We have applied this calculation to the data published by Buddington and Leonard (1953) for an amphibole from the Tupper Lake quadrangle district of the NW Adirondacks, New York, a sample of which was kindly sent to us by Professor Buddington. We have determined the following additional data for this amphibole, $a \sin\beta$ 9·55, b 18·14, c 5·33 Å. giving a volume for the unit cell of $923{\cdot}4\times10^{-24}$ c.c. $\pm 0{\cdot}7$ %. The published density is 3·211 in which a probable error of 0·15 % is assumed.

Table I shows the chemical analysis and the numbers of ions derived

TABLE I. Calculation of chemical analysis of amphibole from Tupper Lake, New York.

Analyst, Eileen K. Oslund (Buddington & Leonard, 1953, p. 894, table I, no. 1).

	(1). Analysis.	(2). No. of cations per unit cell.	(3). No. of anions per unit cell.
SiO_2	39·78	11·86	$23{\cdot}72_0$
Al_2O_3	11·39	4·00	$6{\cdot}00_0$
TiO_2	1·47	0·33	$0{\cdot}65_6$
Fe_2O_3	5·93	1·33	$1{\cdot}99_2$
FeO	14·21	3·54	$3{\cdot}54_2$
MgO	9·62	4·27	$4{\cdot}27_2$
MnO	0·68	0·17	$0{\cdot}17_2$
CaO	9·68	3·09	$3{\cdot}09_2$
Na_2O	1·57	0·91	$0{\cdot}45_4$
K_2O	1·60	0·61	$0{\cdot}30_4$
H_2O+	2·59	5·15	$2{\cdot}57_4$
H_2O-	0·25	—	—
F	1·29	—	$1{\cdot}21_6$
Cl	0·58	—	$0{\cdot}29_2$
Total	100·64	35·26	$48{\cdot}28_6$
Less O for F and Cl ...	0·67	—	$0{\cdot}75_4$
	99·97	Anion total	$47{\cdot}53_2$

from it by this 'direct' method. When these are halved the numbers of ions for comparison with the ideal formula are as follows:

Ca	1·546	Fe″	1·771	Si	5·930	F	0·608	H	2·574
Na	0·454	Mg	2·136	Al	2·000	Cl	0·146		
K	0·304	Mn	0·086		7·930	O	23·011		
	2·304	Fe‴	0·664				23·765		
		Ti	0·164						
			4·826						

Since the sample analysed contained 0·25 % H_2O −, 99·75 was used instead of 100 in the denominator of the expression quoted. Column 3 in table I is obtained by substituting n for m.

In his paper Hey (1954) points out the need for using in the formula derivation a density value corrected for the presence of H_2O −. When this is done in the case of the Tupper Lake amphibole the anion total comes even closer to the value assumed by Buddington and Leonard (23·89 compared with 24). It is clear that if the sample used for density determination does contain adsorbed water then the correction must be made, and ideally a separate water determination should be made on grains in the condition of those whose density is determined. If this has not been done a decision as to whether a correction should or should not be applied may depend on the texture of the specimen concerned. For example, if the grains used for density measurement are compact crystals of moderate size no correction should be made, since any H_2O- found is probably adsorbed only on the ground powder prior to analysis. Where the mineral is fibrous it is reasonable to assume that some of the H_2O- is present for both analysis and density determination, and a correction should be made. As Hey emphasized, the correction may be important, since 1 % H_2O- affects the density by approximately 2 %. Generally when H_2O- is high it is most likely that it is present initially and is not merely picked up on grinding. In the case under discussion here the nature of the crystals used for density measurement suggests that little if any adsorbed water was present. The measured density may be a little low through crystal imperfections and the true value may lie between that measured and the figure obtained by making the correction for H_2O-. Using such a value would give an anion content closer to 24 than the 23·77 quoted here and would raise slightly the values for the cation numbers. Allied to this question of H_2O- is the consideration suggested by Dr. Hey that if 1·44 out of the 2·59 % of H_2O+ is in fact H_2O-, then a calculation will show that the number of H ions is such as to make (OH,F,Cl) = 2. When only 1·15 % H_2O is assumed to be structural water and an appropriate density correction is made, the following numbers of ions are obtained:

$$Ca_{1\cdot63}Na_{0\cdot48}K_{0\cdot32}Fe''_{1\cdot87}Mg_{2\cdot26}Mn_{0\cdot09}Fe'''_{0\cdot70}Ti_{0\cdot18}Si_{6\cdot26}Al_{2\cdot11}H_{1\cdot21}$$
$$F_{0\cdot64}Cl_{0\cdot15}O_{23\cdot54}$$

which may be rewritten as:

$$(Ca,Na,K,Mn,Mg)_{2\cdot90}(Fe''Mg,Fe''',Ti,Al)_{5\cdot00}(Si,Al)_{8\cdot00}O_{22\cdot33}(OH,F,Cl)_{2\cdot00}.$$

The anion total (24·33) is seen to differ more significantly from 24 and

the new figures involve a much greater occupation of the 'A' sites by cations. Since the state of the mineral does not suggest a large amount of adsorbed water we feel that the formula originally derived is more likely. That the extra H ions present are not attended by an appropriate excess of O ions is shown by the anion total, 23·77[1] which is hardly significantly different from that assumed by Buddington in deriving his formula. It may therefore be concluded that the high value of (OH+F+Cl) cannot be attributed in this case to the presence of (OH) ions or water molecules in the 'A' sites of the structure. It is more probable that the extra H ions are linked to oxygens as (OH) replacing O. This replacement may be compensated by a deficiency of cations in the Z sites as suggested for the hydrogrossular structure (Hutton, 1943) and for certain 'sheet' structures (McConnell, 1950, 1951). It is conceivable that it could occur in 'chains' of the amphibole type but such an interpretation can only be made with confidence if the deficiency of cations is substantial and is closely balanced by the excess of hydrogen. Alternatively the (OH)–O replacement may be balanced by the substitution of any cation by one of lower valency. The balancing of extra H ions which occurs in the Tupper Lake amphibole cannot yet be specified since the formula may be written either as

$$(Ca,Na,K)_{2\cdot30}(Mn,Fe'',Mg,Fe''',Ti)_{4\cdot76}(Si,Al,Ti)_{8\cdot00}O_{20\cdot44}(OH,F,Cl)_{3\cdot33}$$

or as

$$(Ca,Na,K,Mn)_{2\cdot39}(Mn,Fe'',Mg,Fe''',Ti,Al)_{5\cdot00}$$
$$(Si,(H_4),Al)_{8\cdot00}O_{21\cdot77}(OH,F,Cl)_{2\cdot00}.$$

A further case of an amphibole with high water content (from Otago, New Zealand) has been investigated, and a direct calculation again shows extra H ions with no extra oxygen. Confirmation that the 'A' sites are indeed empty in this amphibole has been obtained in the course of an X-ray structure analysis. Full details are to be published elsewhere.

Hey has advocated that the proportion of an oxide in a mineral should be expressed for the purpose of the calculation as P/S, where S = analysis total minus impurities, rather than $P/(100 - \text{impurities})$ as suggested here. The former procedure has the effect of spreading any errors in P values more or less evenly over the whole analysis as far as the cation numbers are concerned and will also give an anion total

[1] Using the method described by Hey (1954), the probable error in this figure is estimated to be ±0·19.

nearer the true value. If one's interest is mainly in obtaining an anion total as near as possible to the true value, clearly this is the best course to adopt. Such a case would be one where a comparison is to be made between the actual anion total and that corresponding to a structural concept. We wish to point out, however, that in many circumstances it may be preferable to use 100 instead of the analysis total, since this is the only way to obtain correct cation numbers in all cases where the corresponding P value is correct. In other words, an error in any one oxide determination will not influence the numbers obtained for all other cations. (An exception to this occurs where the error is such that some of an oxide should be regarded as impurity (e.g. if some H_2O- has been included in the figure for H_2O+). Use of 100 is advisable for instance if it is of prime importance to determine accurately the number of Si ions in order to see whether all the tetrahedral positions are filled by them. Furthermore, in cases where there is little uncertainty as to the number of anions structurally possible, calculation using 100 will give an anion total which is erroneous but instructively so. Suppose that F and Cl had not been determined in the Tupper Lake amphibole: table II shows the result of (1) calculating a formula on the basis of

TABLE II. Calculation of formula with omission of F and Cl.

	(1).	(2).		(1).	(2).
Si	6·09	5·93	K	0·31	0·30
Al	2·05	2·00	H	2·64	2·57
Ti	0·17	0·17	F	—	—
Fe‴	0·68	0·66	Cl	—	—
Mg	2·19	2·14	O	24·00	23·39
Fe″	1·82	1·77	*X*	2·36	2·30
Mn	0·09	0·09	*Y*	5·09	4·76
Ca	1·59	1·55	*Z*	8·00	8·00
Na	0·46	0·45	Total anions	24·00	23·39

(1) Calculated on basis of 24 anions. (Note: appreciable Al in *Y* groups, no Ti in *Z*, compared with (2) where all Al and approximately half Ti is in *Z* group.)
(2) Calculated using weight of cell contents. (Note: suspiciously low anion content.)

24 anions; (2) applying the direct calculation using 100 and not 'analysis total'. It is seen that the first method cannot indicate omission of F and Cl and gives erroneous cation numbers. The second gives correct cation numbers and the low anion total suggests that some anions have been missed in analysis. It may be argued that this is already suggested by the low analysis total, but in that case there is no indication whether the deficiency is of F, Cl, or an oxide. By the direct calculation, if an

oxide had been omitted or if an erroneously low value had been reported this would show as a deficiency in both anion and cation total, and in some circumstances could be recognized as such. Using 'analysis total' tends to give an anion total nearer the true value in spite of a faulty analysis by 'spreading the error'. No hard ruling can be laid down as to which factor is best used, and in fact there is no reason why both calculations should not be done. One gives correct cation values for all correct P values, and an anion total (strictly in accord with the analysis) which is affected by experimental errors, and by omissions; the other gives a nearer approximation to the true anion and cation total 'compensating' in part for chemical errors and omissions.

Finally, we wish to point out an important aspect of the direct calculations which may be of considerable value. It is that the number of cations of a particular type can be determined by this method when P for its oxide alone is known (the same applies to any one anion if its P value is known). Thus a partial analysis can be carried out and information obtained about a chosen few ions of particular interest.

Our warmest thanks are due to Dr. M. H. Hey who allowed access to much of his work prior to its publication and has been so kindly and helpfully critical of ours.

References.

Buddington (A. F.) and Leonard (B. F.), 1953. Amer. Min., vol. 38, p. 891 [M.A. **12**–374.]

Hey (M. H.), 1939. Min. Mag., vol. 25, p. 402.

—— 1954. Min. Mag., vol. 30, p. 481.

Hutton (C. O.), 1940. Mem. Geol. Surv. New Zealand, no. 5, p. 15.

—— 1943. Trans. Roy. Soc. New Zealand, vol. 73, p. 174. [M.A. **9**–61.]

McConnell (D.), 1950. Amer. Min., vol. 35, p. 166. [M.A. **11**–220.]

—— 1951. Clay Min. Bull., vol. 1, p. 179.

Warren (B. E.), 1930. Zeits. Krist., vol. 72, p. 493. [M.A. **4**–278.]

On the occurrence of the rare copper molybdate, lindgrenite, at Brandy Gill, Carrock Fell, Cumberland.

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and J. Hartley, B.Sc., F.G.S.
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[Taken as read June 10, 1954.]

LINDGRENITE, a basic copper molybdate $Cu_3(MoO_4)_2(OH)_2$, was first described in 1935 by Palache[1] from the oxidized zone of the great copper deposit at Chuquicamata, province of Antofagasta, Chile. A second occurrence has been recently described[2] from the Helena mine in the Seven Devils mining district, Adams Co., Idaho, the first recorded in the U.S.A. In this paper we are able to record a third occurrence; this time in Cumberland, adding another species to the list of British minerals.

The presence of the lead molybdate, wulfenite ($PbMoO_4$), in the higher part of Brandy Gill, at the western end of Carrock Fell, has been known for some time.[3] The precise locality where it has been found is on a small dump, in the centre of the gill, about three-quarters of the way up, which was derived from an old trial-level driven eastward, from the east side of the gill, on a short east-west lead vein.[4] There is another old trial-level, on the same vein, on the western side of the gill, which again has produced a number of rare and interesting minerals. It is, however, essential to differentiate between the two, although they are so close together, as the conditions that appear to have influenced the formation of some of the minerals found on the two dumps have a direct bearing on their occurrence.

The finding and identification by ourselves in 1949 (and subsequent

[1] C. Palache, Lindgrenite, a new mineral. Amer. Min., 1935, vol. 20, pp. 484–491. [M.A. **6**–147.]

[2] R. S. Cannon and F. S. Grimaldi, Lindgrenite and cuprotungstite from the Seven Devils district, Idaho. Amer. Min., 1953, vol. 38, pp. 903–911. [M.A. **12**–400.]

[3] J. G. Goodchild, Geol. Mag., 1875, decade 2, vol. 2, p. 565.

[4] As is often the case with such veins in the district, small amounts of copper are generally present, and the mineral contents of the vein may be variable over short distances.

years) of the lead tungstate, stolzite ($PbWO_4$), from the other trial on this same vein on the opposite, i.e. western, side of the gill, as well as on this small centre dump from the eastern level in 1951, suggested that there were undoubtedly intersections between the east-west lead vein and some of the north-south granitic suite of veins, which, farther south in and near Grainsgill, carry molybdenite, scheelite, wolframite, &c. Fragments of veinstone belonging to the granitic suite occur on the centre dump, and though it has not been possible to observe any such intersections on the eastern side, we have, nevertheless, found them in situ on the western side, the granitic veins in each case being slightly shifted by the east-west vein.[1]

Although we have recently found a number of rare and unusual minerals from this particular locality in higher Brandy Gill, the discovery on the centre dump, in 1952, of traces of a dark olive-green material in some of the altered granophyre which forms the wall- and country-rock of the veins, suggested something out of the ordinary. As the result of breaking up a considerable amount of material, several small cavities were found in which were some minute, dark olive-green crystals, implanted on a pale yellowish-green crystalline mineral.

The granophyre in which they occur is considerably altered, and had every indication of having come from near one of the walls of the vein, as it was almost identical with similar altered granophyre which we found in situ forming the walls of the vein on the western side of the gill.

At first sight, these dark olive-green crystals rather suggested the copper arsenate, olivenite, but further examination showed that they were almost certainly not olivenite and were probably monoclinic; their identity, however, remained quite unknown.

Microchemical tests of the dark olive-green crystals have shown the presence of copper and molybdenum, and X-ray powder photographs (fig. 1), taken by Hartley at Leeds, have shown them to be lindgrenite, the pattern and spacings agreeing exactly with those of lindgrenite from the type locality, a photograph (fig. 1) of which was fortunately in the film library in the Department of Geology of the University of Leeds.

The yellowish-green crystalline mineral associated with the lindgrenite gives a pattern and spacings very close to those of the well-known pale blue Cumberland plumbogummite, identical yellowish-green specimens of which we have found elsewhere in the district and in Cornwall.

[1] The wulfenite was found only on the centre dump from the eastern level, and, so far, we have found no trace of molybdenum minerals on the west side.

In habit, the lindgrenite crystals from Brandy Gill show marked differences from the Chuquicamata and recently described Idaho specimens. They are all tabular-prismatic parallel to *a* (100), elongated in the

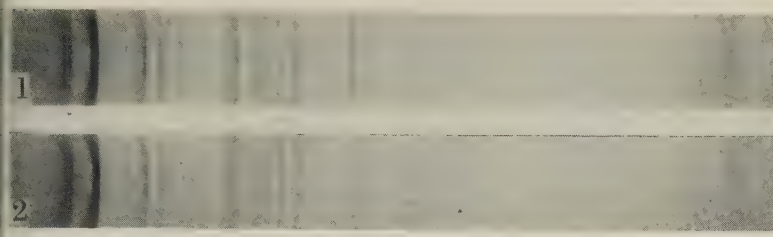

FIG. 1. X-ray powder patterns of lindgrenite, taken on 9-cm.-diameter camera, Cu-$K\alpha$ radiation (λ = 1·542 Å.). 1. Chuquicamata, Chile. 2. Brandy Gill, Cumberland.

direction [001], the largest being about $1\frac{1}{2}$ mm. long: one of the most typical crystals (0·6 × 0·4 mm.) was detached and measured on a two-circle goniometer at Oxford by P. G. Embrey, who obtained measurements (table I) in close agreement with those of Palache.[1]

TABLE I. Forms and measured angles of crystals of lindgrenite from Brandy Gill, Cumberland. (Orientation of Palache.)

						Palache.			
		Mean.*			Mean.		Calc.	
Forms.	Faces.	ϕ.	ρ.	Quality.	ϕ.	ρ.	ϕ.	ρ.
c 001	1	90° 00′	2° 17′	Fair	90° 00′	2° 15′	90° 00′	2° 12′
b 010	2	0 00	90 00	Fair	0 00	90 00	0 00	90 00
a 100	2	90 00	90 00	Good	90 00	90 00	90 00	90 00
r 121	2	41 20½	53 49½	Fair	41 18	53 47½	41 20	53 46½
t $\bar{1}31$	2	−28 10½	60 21	Poor (v. small)	−28 13½	60 10	−28 13	60 10½
101?	1	Not measurable		—	Not found		—	

* Individual measurements: *b*(010), ϕ −0° 7′, 180° 8′; *r*(121), ϕ 41° 25′, 41° 16′, ρ 53° 43′ 53° 58′; *t*($\bar{1}$31), ϕ −28° 6′, −28° 15′, ρ 60° 10′, 60° 32′.

The crystals (fig. 2) all show well-developed faces of *a* (100) and *b* (010), the *a* (100) faces being the more prominent and giving the crystals a tabular development parallel to them, whereas the Chilean and Idaho crystals show the tabular habit parallel to the *b* (010) faces: in the Brandy Gill crystals, too, the *a* (100) faces are usually vertically striated.

[1] The indices and letters of Palache are retained in lieu of the new setting in Dana's System of mineralogy, 7th ed. 1951, vol. 2, p. 1094, which is based on the X-ray unit cell of W. H. Barnes, Amer. Min., 1949, vol. 34, p. 163, correction, p. 611. [M.A. **10**–537, **11**–101.]

Two faces of r (121) are present on all the Brandy Gill crystals, while many of them also show two very narrow faces of t ($\bar{1}31$) on the opposite side: in every case there is a small but conspicuous face of c (001). Some of the crystals are doubly-terminated and show the same forms at each end. On a number of crystals a narrow face is visible between the two r (121) faces. On the crystal measured by Embrey, although this small face gave a good reflection, both under a hand-lens and under the microscope, it was found impossible to obtain a signal. It appears to lie midway between ($1\bar{2}1$) and (121), and if a genuine face (as seems likely) it is probably the orthodome (101), a new form (fig. 2, i and iii).

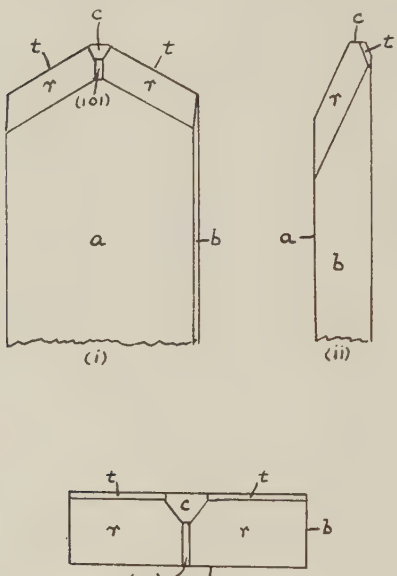

FIG. 2 Crystals of lindgrenite from Brandy Gill, Cumberland. (Actual size, approx. 1 mm. long.)

Through the courtesy of Miss J. M. Sweet, we have been able to examine several specimens of lindgrenite from Chuquicamata in the British Museum collection: these all show the thin platy habit, parallel to b (010), mentioned by both Palache and Dana as being the general habit of the mineral. Palache also mentions that a few of the very smallest crystals were acicular prisms, with a square cross-section, and that the terminal face, c (001), was present only on a few crystals of tabular habit. In all these respects, therefore, the Brandy Gill crystals show considerable differences.

This occurrence of lindgrenite at Brandy Gill is perhaps one of the most interesting additions to the remarkable number of rare and unusual minerals that have recently come to light during our investigations in the Caldbeck district.

Twentieth list of new mineral names.[1]

By L. J. Spencer, C.B.E., M.A., Sc.D., F.R.S.

Formerly Keeper of Minerals in the British Museum.

[Communicated June 9, 1955.]

Aldanite. M. M. Bespalov, 1941. Soviet Geology, 1941, no. 6, p. 107 (алданит). $k\mathrm{ThO_2}.l\mathrm{UO_2}.m\mathrm{UO_3}.n\mathrm{PbO}$, cubic, thorianite group. Named from the locality, Aldan region, eastern Siberia. (18th List.) [M.A. **12**–60.]

Alkali-oxyapatite. V. I. Vlodovetz, 1933. Trans. Arctic Inst., vol. 2, p. 84 (щелочной окси-апатит), p. 99 (alkaline oxyapatite). O. M. Shubnikova, Trans. Lomonosov Inst., 1936, no. 7, p. 328 (щелочной оксиапатит, alkali-oxyapatite). Apatite containing $\mathrm{Na_2O}$ 1·37 % replacing CaO, and O partly replacing (F,OH).

Aluminiumskorodit, Alumoskorodit, Alumskorodit. K. F. Chudoba, 1954. Hintze, Min., Ergbd. 2, pp. 8, 10, 11. Synonyms of Aluminoscorodite (18th List). Unnecessary complications.

Aluminous-serpentine. H. S. Yoder, 1952. Amer. Journ. Sci., Bowen volume, p. 579 (Aluminous-Serpentine, aluminous serpentine, Al-serpentine). Artificially produced, platy habit, related to antigorite or clinochlore. Compare Alumino-chrysotile, 17th List. [M.A. **12**–83.]

Alumogel. (Author?). H. Strunz, Min. Tab., 1941, p. 111 (Alumogel). Amorphous aluminium hydroxide, '$\mathrm{AlOOH}+\mathrm{aq}$.' Synonym of kiachite (5th List) and sporogelite (6th List). Compare Siderogel (19th List).

Alvarolite. W. Florencio, 1952. Anais Acad. Brasil. Cienc., vol. 24, p. 261 (Alvarolita). Perhaps monoclinic $\mathrm{MnTa_2O_6}$ dimorphous with manganotantalite [cf. Min. Mag. **27** 162]. Named after Admiral Alvaro Alberto da Motta e Silva, director of the national research council, Brazil. [M.A. **12**–305.]

Ammonium-aphthitalite. C. Frondel, 1950. Amer. Min., vol. 35, p. 596 (ammonian aphthitalite). A variety of aphthitalite containing $(\mathrm{NH_4})_2\mathrm{SO_4}$ 5·68 %, $(\mathrm{K,NH_4})_3\mathrm{Na}(\mathrm{SO_4})_2$, hexagonal. From Guañape Islands, Peru. [M.A. **11**–302.]

[1] Previous lists in this series have been given every three years at the ends of vols. 11–29 (1897–1952) of this Magazine. The present list includes 219 names, bringing the total up to 3153, since the sixth edition (1892) of Dana's 'System of Mineralogy'. References to 'Mineralogical Abstracts' are given in the form [M.A. **12**–].

Ammonium-mica. J. W. Gruner, 1939. Amer. Min., vol. 24, p. 42[illegible] (Ammonium mica). Hintze, Min., 1954, Ergbd. 2, p. 12 (Ammonium glimmer). An artificial product produced by the action of H_2O_2 and NH_4OH on vermiculite. [M.A. **7**-479.]

Analbite. H. L. Alling, 1936. Interpretative petrology of igneous rocks, p. 59 (low-temperature triclinic β-$NaAlSi_3O_8$).

—— F. Laves, 1952. Journ. Geol. Chicago, vol. 60, p. 570 (low-temperature albite; p. 571, anperthite containing exsolved analbite; p. 572, anplagioclases). Not the analbite of A. N. Winchell (11th List) or of H. L. Alling (above). [M.A. **12**–136.]

Arsenatapatit. Synonym of svabite. *See* Bleiapatit.

Arsenosulvanite. A. G. Betekhtin, 1941. Mém. Soc. Russ. Min., vol. 70, p. 161 (арсеносульванит). V. I. Mikkeev, ibid., p. 165. Isomorphous with sulvanite (2nd List) with vanadium largely replaced by arsenic, $Cu_3(As,V)S_4$, cubic: from Mongolia. [M.A. **12**–460.]

Arsenstruvite. (Author?). H. Strunz, Min. Tab., 1949, p. 172 (Arsenstruvit). $NH_4MgAsO_4.6H_2O$, like struvite with As in place of P. Presumably an artificial product.

Avelinoite. M. L. Lindberg and W. T. Pecora, 1954. Science (Amer. Assoc. Adv. Sci.), vol. 120, p. 1074. Hydrous sodium ferric phosphate $NaFe_3'''(PO_4)_2(OH)_4.2H_2O$, tetragonal, from Brazil. Named after Avelino Ignacio de Oliveira, Brazilian geologist. [M.A. **12** 512.]

Barbosalite. M. L. Lindberg and W. T. Pecora, 1954. Science (Amer. Assoc. Adv. Sci.), vol. 119, p. 739. Hydrous ferrous ferric phosphate, $Fe''Fe'''(PO_4)_2(OH)_2$, as black grains from Brazil. Named after Prof. A. L. de M. Barbosa, School of Mines. Minas Geraes. *See* Ferro-ferric-lazulite. [M.A. **12**–408.]

Barium-priderite. K. Norrish, 1951. Min. Mag., vol. 29, p. 506 (Ba-priderite). Hintze, Min., 1954, Ergbd. 2, p. 31 (Barium-Priderit). The natural mineral priderite (19th List) contains BaO 6·7, K_2O 5·6 %. Ba-priderite and K-priderite (q.v.) were prepared artificially.

Belovite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2, vol. 82, p. 317 (Беловит). '$Ca_3(Ca,Mg)(AsO_4)_2.2H_2O$', near roselite. [M.A. **12**-352.]

—— L. S. Borodin and M. E. Kazakova, 1954. Doklady Acad. Sci. USSR, vol. 96, p. 613 (Беловит). An apatite-like mineral from pegmatite, hexagonal, $(Sr,Ce,Na,Ca)_{10}(PO_4)_6(O,OH)_2$. Named after academician N. V. Belov, Н. В. Белов, of Moscow. [M.A. **12**–461.]

Beryllite. M. V. Kuzmenko, 1954. Doklady Acad. Sci. USSR, vol. 9, p. 451 (бериллит). Hydrous silicate of beryllium, $Be_3SiO_4(OH)_2.H_2O$, s an alteration product of epididymite. [M.A. **12**–569.]

Bleiapatit, &c. F. Machatschki, 1953. Spezielle Mineralogie, Wien, . 330. In the apatite family, pyromorphite is named Bleiapatit. imilarly, Arsenatapatit = svabite, Bleiarsenatapatit = mimetite, Bleivanadatapatit = vanadinite, Silikatsulfatapatit = wilkeite, ererdensilikatapatit = britholite, Yttererdensilikatapatit = abukualite. [M.A. **12**–232.]

Bøggildite. R. Bøgvad, 1952 (MS.). A. H. Nielsen, Acta Chem. cand., 1954, vol. 8, p. 136. A fluoride $Na_2Sr_2Al_2(PO_4)F_9$ from the reenland cryolite deposit. Named after Ove Balthasar Bøggild .872–), emeritus professor of mineralogy in the university of Copenagen. [M.A. **12**–14, 353.]

Bouazzerite. Name found on a dealer's label by J. Paclt, Neues ahrb. Min., Monatshefte, 1953, p. 188 (Bouazzerit). A ferriferous ariety of stichtite from Bou Azzer, Morocco. [M.A. **9**-121, **12**–239.]

Burbankite. W. T. Pecora and J. H. Kerr, 1953. Amer. Min., vol. 3, p. 1169. $(Ca,Sr,Ba,Ce,Na)_6(CO_3)_5$ as pale yellow hexagonal crystals ith other rare-earth carbonates from Montana. Named after Wilbur wett Burbank (1898–) of the United States Geological Survey. M.A. **12**–301.]

Calciouraconite. A. K. Boldyrev, 1935. Kurs opisatelnoi mineralogii, eningrad, pt. 3, p. 83 (Кальцио-ураконит). Variety of uraconite conining 3 % CaO.

Calcium-analcime. A. Steiner, 1955. Min. Mag., vol. 30, p. 695. rtificial $CaAl_2Si_4O_{12}.2H_2O$, analogous to analcime with Ca in place of a. Synonym of wairakite (q.v.).

Calcium-uranospinite. M. E. Mrose, 1953. Amer. Min., vol. 38, 1159 (calcium-uranospinite). Synonym of uranospinite, as applied the artificial product. Compare hydrogen-uranospinite, &c. (19th ist). [M.A. **12**–445.]

Calkinsite. W. T. Pecora and J. H. Kerr, 1953. Amer. Min., vol. 38, 1169. Hydrous carbonate of rare-earths, $(La,Ce,Nd,Pr)_2(CO_3)_2.4H_2O$, minute pale-yellow orthorhombic plates from Montana. An alteraon product of burbankite (q.v.). Named after Frank Cathcart Calkins 878–) of the United States Geological Survey. [M.A. **12** 301.]

Callaghanite. C. W. Beck and J. H. Burns, 1953. Progr. & Abstr. in. Soc. Amer., p. 10; Amer. Min., 1954, vol. 39, p. 316, 630. $Mg_4Mg_4Ca(OH)_{14}(CO_3)_2.2H_2O$, blue monoclinic crystals in dolomite-rock om Gabba, Nevada. Named after Dr. Eugene Callaghan, director of ıe New Mexico Bureau of Mines. [M.A. **12**–304, 410.]

Carbonate-hydrotalcite. D. M. Roy, R. Roy, and E. F. Osbor 1953. Amer. Journ. Sci., vol. 251, p. 355. Synonym of hydrotalci *See* Nitrate-hydrotalcite. [M.A. **12**–196.]

Cardenite. D. M. C. MacEwan, 1954. Clay Min. Bull., vol. 2, p. 12 'A trioctahedral montmorillonoid derived from biotite' in soil-clay a Carden Wood and other places in Aberdeenshire. A mixed alterati product previously described, without name, by G. F. Walker in Mi Mag. **29**–72.

Caustobiolites, Caustolites. Group-names for combustible orga substances. H. Potonié, Die Entstehung der Steinkohle und Kaust biolithe, Berlin, 1910, p. 1. A. W. Grabau, Textbook of geolo New York, 1920, pt. 1, p. 270 (Caustolith). J. Paclt, Tschermaks M Petr. Mitt., 1953, ser. 3, vol. 3, p. 332 (Caustolites). [M.A. **12**–306.]

Cheralite. S. H. U. Bowie and J. E. T. Horne, 1953. Min. Ma vol. 30, p. 93. A member of the monazite group rich in thorium (Th 31·50 %), $(Ce,La,Th,U,Ca)(P,Si)O_4$, as green monoclinic crystals pegmatite from Travancore. Named from Chera (Kerala), an ancie kingdom in SW. India.

Chiklite. S. A. Bilgrami, 1955. Min. Mag., vol. 30, p. 634. A manga nese amphibole in manganese ore from Chikla, Bhandara, India. Name from the locality.

Chilkinite, Schilkinit. French (Bull. Soc. Franç. Min. Crist., 1951 vol. 74, p. 182) and German (Hintze, Min., 1954, Ergbd. 2, p. 349 transliterations of шилкинит, shilkinite (16th List).

Chinoite. C. W. Beck and D. B. Givens, 1953. Amer. Min., vol. 38 p. 191. A basic copper phosphate from Chino mine, New Mexico. Late proved to be identical with libethenite. [M.A. **12**–132, 462.]

Chlor-spodiosite. F. K. Cameron and W. J. McCaughey, 1911 Journ. Physical Chem., vol. 15, p. 468. Artificially produced Ca_2PO_4Cl isomorphous with spodiosite with chlorine in place of fluorine. [Min Mag. **30**–166.]

Clino-chevkinite. S. Bonatti and G. Gottardi, 1953. Rend. Soc Min. Ital., vol. 9, p. 242 (clino-chevkinite); ibid., 1954, vol. 10, p. 22 (clinochevkinite). Monoclinic chevkinite from Urals (A. K. Boldyrev 1924, M.A. **3**–405), as distinct from orthorhombic chevkinite fro Madagascar (A. Lacroix, 1915). *See* Ortho-chevkinite. [M.A. **12**-24 498.]

Clino-chrysotile, ortho-chrysotile. E. J. W. Whittaker, 195 Acta Cryst., vol. 4, p. 187; 1952, vol. 5, p. 143. Monoclinic and ortho rhombic forms of chrysotile, as determined by X-rays. [M.A. **11**–43 539.]

Coesite. R. B. Sosman, 1954. Science (Amer Assoc. Adv. Sci.), ol. 119, p. 738 (coesite), p. 739 (silica C). A high-pressure form of dense p. gr. 3·01) silica, probably triclinic, prepared under dry conditions by Coes, after whom it is named. [M.A. **12**–410.]

Coffinite. A. D. Weeks and M. E. Thompson, 1954. [Bull. U.S. eol. Surv., no. 1009-B, p. 31] abstract in Amer. Min., 1954, vol. 39, 1037. L. R. Steiff, J. W. Stern, and A. M. Sherwood, Science (Amer. ssoc. Adv. Sci.), 1955, vol. 121, p. 608. Uranium silicate, $U(SiO_4)_{1-x}$ $)H)_{4x}$, tetragonal, as a black impregnation in sandstone on the Colorado ateau. Named after Reuben Clare Coffin of the Colorado Geological rvey. [M.A. **12**–566–7, 586–7.]

Correnside. F. Lippmann, 1954. Heidelberg. Beitr. Min. Petr., vol. p. 134 (Correnside). A 'swelling' chloritic mineral determined by -rays in the finest fraction of red Keuper clay. Named after Prof. rl Wilhelm Correns (1893–) of Göttingen.

Corundophyllite. A. Des Cloizeaux, Manuel Min., 1862 93; A. de pparent, Cours Min., 1st–4th edit., 1884–1908; variable entries text and indexes, corundophilite, corundophyllite. J. Orcel, Compt. end. Acad. Sci., Paris, 1924, vol. 178, p. 1730 (corundophyllite). ror for corundophilite, named from *φίλος*, friend of corundum, of hich it is an alteration product. [M.A. **3**–56, 372.]

Cryohalite. (Author?). A. E. Fersman and O. M. Shubnikova, ochem. Min. Companion, Moscow, 1937, p. 160 (криогалит, $aCl.10H_2O$). Eutectic mixture of ice and hydrohalite ($NaCl.2H_2O$). med from *κρύος*, frost, and halite. Compare cryohydrate (F. Guthrie, 74). *See* Maakite. [M.A. **12**–240.]

Cupromontmorillonite. F. V. Chukhrov and F. Y. Anosov, 1950. m. Soc. Russ. Min., ser. 2, vol. 79, p. 26 (медмонтит, купромонтмо-ллонит). I. D. Sedletzky, Priroda, Acad. Sci. USSR, 1950, vol. 39, . 10, p. 48 (купромонтмориллонит). Correction to 19th List. [M.A. 2–239.]

Cuprozippeite. A. K. Boldyrev, 1935. Kurs opisatelnoi mineralogii, ningrad, pt. 3, p. 83 (Купроциппеит). Variety of zippeite containing % CuO.

Cyrilovite. M. Novotný and J. Staněk, 1953. Acta Acad. Sci. Nat. ravo-Silesicae, vol. 25, p. 325 (cyrilovit). Brown tetragonal crystals, $'e_2O_3.3P_2O_5.5\frac{1}{3}H_2O$; in pegmatite from Cyrilov, Moravia. Named m the locality. [M.A. **12**–512.]

Eisenchrysotil. F. Machatschki, 1953. Spezielle Mineralogie, Wien, 350. Given as a synonym of 'Greenolith' (error for greenalite, 4th st). Not the same as ferro-chrysotile (14th List) and iron-serpentine 5th List).

Eisenrichterit. M. Belowsky, 1905. Zeits. Deutsch. Geol. Gese vol. 57, p. 33. A fibrous blue amphibole from Greenland, allied t richterite ('astochite') with iron in place of manganese. (The compo tion was calculated from a rock analysis after deducting 76 % felspar.) *See* Iron-richterite, Ferririchterite.

Eitelite. C. Milton, J. M. Axelrod, and F. S. Grimaldi, 1954. B Geol. Soc. Amer. [1955], vol. 65, no. 12 (for 1954), p. 1286 (abstra $Na_2O.MgO.2CO_3$ hexagonal, from an oil well in Utah. Named aft Wilhelm (Hermann Julius) Eitel (1891–), director of the Institute Silicate Research in the University of Toledo, Ohio. [M.A. **12**–511.]

Evenkite. A. V. Skropyshev, 1953. Doklady Acad. Sci. USSR, 88, p. 719 (эвенкит). Paraffin wax, $C_{12}H_{42}$, as white, optically bia scales in a vein of sulphide ores from the district of the Evenki peo Lower Tunguska river, Siberia. [M.A. **12**–305.]

Faheyite. M. L. Lindberg and K. J. Murata, 1952. Bull. Geol. S Amer. [1953], vol. 63, no. 12 (for 1952), p. 1275 (abstract); Amer. M 1953, vol. 38, pp. 263, 349. $(Mn,Mg,Na)Be_2Fe_2'''(PO_4)_4.6H_2O$, hexago as white fibres in pegmatite from Brazil. Named after Dr. Joseph Jo Fahey (1901–), geochemist, United States Geological Survey. preliminary notice of the title of the paper, Amer. Min., Nov.–De 1952, vol. 37, p. x, gives the form faheylite. [M.A. **12**–131.]

Farallonite. N. N. Kohanowski, 1953. Mines Mag., Denver, Co rado, vol. 43, no. 2, p. 19. Sky-blue chalky material, monoclinic '$2MgO.W_2O_5.SiO_2.nH_2O$?'; an alteration product of wolframite in t Farallon mine, Tasna, Bolivia. Named from the locality. [M.A. **12** 30

Faustite. R. C. Erd, M. D. Foster, and P. D. Proctor, 1953. Am Min., vol. 38, p. 964. The zinc analogue of turquoise; $(Zn,Cu)Al_6(PO_4)$ $(OH)_8.5H_2O$, containing ZnO 7·74, CuO 1·61 %. Fine-grained, appl green masses from Nevada. Named after Dr. George Tobias Fau (1908–) of the United States Geological Survey. [M.A. **12**-302.]

Ferri-chamosite. G. W. Brindley and R. F. Youell, 1953. M Mag., vol. 30, p. 57 (ferric chamosite). Oxidized product of fer chamosite (q.v.) when heated in air or weathered. May be a disti species (? berthierine, Min. Mag. **30**–645).

Ferririchterite. S. A. Bilgrami, 1955. Min. Mag., vol. 30, p. 6 Suggested as a more appropriate name for the manganese amphib juddite. Compare ferrorichterite (18th List). *See* Eisenrichterit, ir richterite.

Ferrite-spinels. P. Ramdohr, 1950. Erzmineralien, Berlin, p. 6 (Ferritspinelle). Collective name for minerals of the magnetite seri ferrite compounds RFe_2O_4 (R = Mg,Fe,Zn,Mn,Zn), in the spinel grou

Ferro-chamosite. G. W. Brindley and R. F. Youell, 1953. Min. ag., vol. 30, p. 57 (ferrous chamosite). Synonym of chamosite. When ated in air or weathered it changes to ferri-chamosite (q.v.).

Ferro-ferri-lazulite. M. A. Gheith, 1953. Amer. Min., vol. 38, p 12 (ferrous ferric lazulite). Artificially produced monoclinic iron hosphate approximating to $Fe''Fe'''_2(PO_4)_2(OH)_2$, isomorphous with zulite with Fe in place of Mg and Al. Later named barbosalite (q.v.). t high temperature it changes over to a tetragonal modification, pscombite (q.v.). [M.A. **12**–238.]

Ferrolazulite. W. E. Tröger, 1952. Tabellen opt. Bestim. gesteins- ld. Minerale, p. 145 (Ferrolazulith). Variety of lazulite containing me FeO replacing MgO. Distinct from scorzalite (18th List) and iron- zulite (19th List).

Ferrorhodochrosile. (Author?). A. E. Fersman and O. M. Shubnikova, Geochem. Min. Companion, 1937, p. 213 (феррородохрозит). Ferriferous variety of rhodochrosite. Compare ponite (6th List).

Fluoroxyapatite. V. I. Vlodovetz, 1933. Trans. Arctic Inst., ol. 12, p. 79 (фтор-окси-апатит), p. 99 (fluorine oxyapatite). O. M. Shubikova, Trans. Lomonosov Inst., 1936, no. 7, p. 328 (фтороксиапатит, uor-oxyapatite).

Gastunite. H. Haberlandt and A. Schiener, 1951. Tschermaks Min. etr. Mitt., ser. 3, vol. 2, p. 307 (Gastunit Nr. 1). Provisional name for n undetermined mineral of the uranotile group. From the hot springs t Bad Gastein, Salzburg. Named from the locality. Compare neoastunite (19th List). [M.A. **11** 433]

Ghassoulite. G. Millot, 1954. Compt. Rend. Acad. Sci. Paris, ol. 238, p. 257. An end-member, $Mg_3Si_4O_{10}(OH)_2$, of the montmorillonite roup, previously referred to sepiolite. Named from the locality, gebel hassoul, Morocco. [M.A. **12**–354.]

Gold argentide. M. P. Lozhechkin, 1939. Doklady Acad. Sci. RSS, vol. 24, p. 454. Synonym of electrum. [M.A. **7**–515.]

Gold cupride. M. P. Lozhechkin, 1939. Doklady Acad. Sci. RSS, vol. 24, p. 451. Synonym of cuproauride (15th List) and auricupride (19th List). [M.A. **7**–514.]

Goldichite. A. Rosenzweig and E. B. Gross, 1954. Bull. Geol. Soc. mer. [1955], vol. 65, no. 12 (for 1954), p. 1299; Amer. Min., 1955, vol. 0, pp. 331, 469. Hydrous potassium ferric sulphate, $KFe(SO_4)_2 \cdot H_2O$, as pale-green monoclinic crystals from the decomposition of yrite. From Utah. Named after Samuel S. Goldich (1909), professor of geology, University of Minnesota. [M.A. **12**–511.]

Görgeyite. H. Mayrhofer, 1953. Neues Jahrb. Min., Monatshef p. 35 (Görgeyit). Hydrated sulphate, $K_2SO_4.5CaSO_4.1\text{–}1\frac{1}{2}H_2O$, sm tabular monoclinic crystals with glauberite, &c., in salt deposits a Ischl, Upper Austria. Named in memory of Dr. Rolf Görgey v Görgö (1886–1915) of Vienna, who wrote on salt deposits. [M.A. 12 132.] Compare mikheevite.

Grovesite. F. A. Bannister, M. H. Hey, and W. C. Smith, 19 Min. Mag., vol. 30, p. 645. A chlorite-like mineral from the Ben manganese mine, Wales. $(Mn,Mg,Al)_3(Si,Al)_2(O,OH)_9$, near pennant (17 List), but with X-ray pattern similar to berthierine and cronstedti suggesting a kaolin- rather than a chlorite-type structure. Named af Dr. Arthur William Groves (1903), of the Imperial Institute, Lond

Habazit, Halkofanit. Double transliterations through Serbi хабазит and халкофанит, of chabazite and chalcophanite. [M.A. 12 483.]

Hagendorfite. H. Strunz, 1954. Neues Jahrb. Min., Monatshef 1954, p. 252 (Hagendorfit). $(Na,Ca)(Fe,Mn)_2(PO_4)_2$, triclinic (? greenish-black. Close to varulite (14th List) and hühnerkobelite (19t List), with Fe > Mn or Na > Ca. Named from the locality, Hagendor Bavaria. [M.A. **12**–462.]

Heikolite. Correct spelling of heikkolite (18th List). [M.A. **12** 595.]

Hexacelsian. B. Yoshiki and K. Matsumoto, 1951. Journ. Amer Ceramic Soc., vol. 34, p. 286. Artificially produced, high-temperature hexagonal modification of $BaAl_2Si_2O_8$. [M.A. **12**-307.]

Hidalgoite. R. L. Smith, F. S. Simons, and A. C. Vlisidis, 195 Amer. Min., vol. 38, p. 1218. Basic sulphate arsenate, $PbAl_3(AsO_4)(SO_4)(OH)_6$, as white, fine-grained masses, hexagonal, from Zimapan Hidalgo state, Mexico. Named from the locality. Since recorded fror France. [M.A. **12**–302, 571.]

Huntite. G. T. Faust, 1953. Amer. Min., vol. 38, p. 4. $Mg_3Ca(CO_3)$ orthorhombic, as a fine-grained white powder in magnesite deposits i Nevada. Named after Dr. Walter Frederick Hunt (1882–), emeritu professor of mineralogy in the University of Michigan. [M.A. **12**–132.]

Hydralsite. D. M. Roy, 1954, Amer. Min., vol. 39, p. 141; R. Ro and E. F. Osborn, ibid., p. 863. Artificial hydrous aluminium silicat perhaps $2Al_2O_3.2SiO_2.H_2O$, produced by the hydrothermal decompos tion of kaolinite. Named from the composition, which would apply many minerals. [M.A. **12**–308, 516.]

Hydrocervantite. L. B. Shlain, 1950. Mém. Soc. Russ. Min., ser. vol. 79, p. 63 (гидросервантит). O. M. Shubnikova, ibid., 1952, vol. 8 p. 45. $Sb_2O_4.nH_2O$, with 5 % H_2O, a variety of cervantite, intermediat between cervantite and stibiconite: alteration product of stibnite.

Hydrocookeite. A. I. Ginzburg, 1953. Doklady Acad. Sci. USSR, vol. 90, p. 871 (гидрокукеит). Hydrated cookeite. [M.A. **12** 451.]

Hydrometavauxite. M. C. Bandy, 1946. Mineralogía de Llallagua, Bolivia, La Paz, p. 57 (Metavauxita Hidratada). M.A. **10** 9 (hydrated metavauxite); Hintze, Min., 1954, Ergbd. 2, p. 166 (Hydrometavauxit). An undetermined, yellow alteration product of metavauxite.

Hydroparavauxite. M. C. Bandy, 1946. Mineralogía de Llallagua, Bolivia, La Paz, p. 57 (Paravauxita hidratada). M.A. **10** 9 (hydrated paravauxite); Hintze, Min., 1954, Ergbd. 2, p. 167 (Hydroparavauxit). An undetermined, yellow, fibrous, alteration product of paravauxite.

Hydroxyl-topaz. W. E. Tröger, 1952. Tabellen opt. Bestim. Gesteinsbild. Minerale, p. 146 (Hydroxyltopas). Synonym of topaz. [M.A. **12**–4.]

Ilmenomagnetite. A. F. Buddington, J. Fahey, and A. Vlisidis, 1953. Progr. & Abstr. Min. Soc. Amer., 1953, p. 13; Amer. Min., 1954, vol. 39, p. 318 (abstract). Titaniferous magnetite containing exsolution ilmenite as distinct from any in solid solution. Compare titanomagnetite (2nd List).

Indialite. A. Miyashiro and T. Iiyama, 1954. Proc. Japan Acad., vol. 30, p. 746. Artificial $Mg_2Al_4Si_5O_{18}$, hexagonal, distinct from orthorhombic cordierite. Also found in sediments fused by a burning coal seam in India. Named from the locality. *See* Osumilite. [M.A. **12**-513, 515.]

Irinite. L. S. Borodin and M. E. Kazakova, 1954. Doklady Acad. Sci. USSR, vol. 97, p. 725 (иринит). A metamict cubic mineral (Na,Ce,Th)(Ti,Nb)$(O,OH)_3$, near loparite. Named after Dr. Irina (Irene) Dmitrievna Borneman-Starynkevich, Ирина Дмитриевна Борнеман-Старынкевич, of the Geol. Min. Inst., Acad. Sci., Moscow. [M.A. **12** 462.]

Iron-berlinite. M. A. Gheith, 1953. Amer. Min., vol. 38, p. 621 (iron berlinite). Artificially produced iron phosphate, $FePO_4$, isomorphous with berlinite (Fe in place of Al) and with the quartz-type structure. *See* Polyquartz. [M.A. **12**–238.]

Iron-richterite. O. B. Bøggild, 1953. Mineralogy of Greenland, Meddel. om Grønland, vol. 149, no. 3, p. 282 (Iron Richterite). Translation of Eisenrichterit (q.v.). *See* also ferririchterite.

Iron-sericite. H. Minato and Y. Takano, 1952. Sci. Papers College Gen. Educ. Univ. Tokyo, vol. 2, p. 194 (iron sericite). A sericitic clay from Japan containing Fe_2O_3 5·74, FeO 1·50 %, MgO trace. *See* Magnesium-sericite. [M.A. **12**–221.]

Iron-uranite. d'A. George, 1949. [U.S. Atomic Energy Comm., RMO–563]; C. Frondel, Min. Mag., 1954, vol. 30, p. 343 ('iron uranite'). An incompletely examined mineral from New Mexico, perhaps the same as bassetite or kahlerite (q.v.).

Isokite. T. Deans and J. D. C. McConnell, 1955. Min. Mag., vol. 30, p. 681. $CaMgPO_4F$, monoclinic, isomorphous with tilasite with P in place of As. White spherulites from a carbonatite plug near Isoka, Northern Rhodesia. Named from the locality.

Ivanovite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2, vol. 82, p. 317 (Ивановит). Hydrous chloro-borate of Ca (and K?), monoclinic (pseudo-hexagonal), Inder salt deposits, Kazakhstan. [M.A. **12**–352.]

Kahlerite. H. Meixner, 1953. Der Karinthin, no. 23, p. 277 (Kahlerit, Eisenarsenuranglimmer). Hydrous arsenate of uranyl and iron, $Fe(UO_2)(AsO_4).8H_2O$, as yellow rectangular plates probably monoclinic, from Hüttenberg, Carinthia. Named after Dr. Fritz Kahler, geologist, of the Carinthian Landesmuseum at Klagenfurt. [M.A. **12**–353; Min. Mag. **30**–344.]

Kamiokalite. K. Sakurai, H. Nagashima, and E. Sorita, 1952. [Syumi-no-Tigaku (Amateur Geologist), vol. 5, p. 170] abstract in Amer. Min., 1955, vol. 40, p. 367 (Kamiokalite). Z. Harada, Journ. Fac. Sci. Hokkaido Univ., 1954, ser. 4, vol. 8, p. 317 (Kaniokaite). Blue monoclinic crystals, $3CuO.3ZnO.P_2O_5.7H_2O$. A variety rich in zinc of veszelite; compare arakawaite (9th List). Named from the locality, Kamioka mine, Japan.

Keatite. R. B. Sosman, 1954. Science (Amer. Assoc. Adv. Sci.), vol. 119, p. 738 (keatite), p. 739 (silica K). A high-pressure tetragonal form of silica prepared hydrothermally by Paul P. Keat, after whom it is named. [M.A. **12**–410.]

Knipovichite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2, vol. 82, p. 317 (Книровичит). Hydrous carbonate of Ca,Al,Cr, radiating fibres, optically biaxial, pink. [M.A. **12**–352.]

Koivinite. A. A. Kukharenko, 1951. Mém. Soc. Russ. Min., ser. 2, vol. 80, p. 238 (койвинит); V. A. Frank-Kamenetzky, A. I. Komkov, and V. V. Nardov, ibid., 1953, vol. 82, p. 297. An incompletely described mineral (locality?) near florencite. Named perhaps from кой (that) and винить (to criticize). [M.A. **12**–411.]

Kokimbit. S. I. Naboko, Bull. Volcan. Station, Kamchatka, 1953, no. 18, p. 53 (кокимбит). Double transliteration of coquimbite. [M.A. **12**–542.]

Kruzhanovskite, Kryjanovskite, Kryschanowskit. American (Amer. Min., 1951, vol. 36, p. 382), French (Bull. Soc. Franç. Min. Crist., 1952, vol. 75, pp. 175, 315), and German (Hintze, Min., 1954, Ergbd. 2, pp. 201, 204) transliterations of крыжановскит, kryzhanovskite (19th List). [M.A. **11**–189.]

Kurgantaite. Y. Y. Yarzhemsky, 1952. Min. Sbornik, Lvov Geol. Soc., no. 6, p. 169 (курантаит). Hydrous metaborate $2(Sr,Ca)O.2B_2O_3.H_2O$. Named from the locality Kurgan-tau (Курган-тау), Inder district, Kazakhstan. [M.A. **12**–513.]

Kuttenbergite. R. Koechlin, 1928. Min. Taschenbuch, Wien, p. 36 (Kuttenbergit). Synonym of Kutnohorite (4th List). Named from the locality Kutná Hora (Czech) = Kuttenberg (German).

Laueite. H. Strunz, 1954. Naturwissenschaften, vol. 41, p. 256 (Laueit). Hydrous basic phosphate, $MnFe_2'''(PO_4)_2(OH)_2.8H_2O$, triclinic, honey-brown, from Hagendorf, Bavaria. Named after Professor Max (Felix Theodor) von Laue (1879 -), of Berlin. [M.A. **12**–410.]

Lead-becquerelite. J. W. Frondel and F. Cuttitta, 1953. Amer. Min., vol. 38, pp. 1019, 1024 (lead-becquerelite). A doubtful variety of becquerelite, perhaps $PbO.6UO_3.11H_2O$. [M.A. **1**–377, **11** 109, **12**–444.]

Likasite. A. Schoep, W. Borchert, and K. Kohler, 1955. Bull. Soc. Franç. Min. Crist., vol. 78, p. 84. Nitrate and phosphate of copper, $Cu_{12}(NO_3)_4(PO_4)_2(OH)_{14}$, as sky-blue orthorhombic plates from Likasi, Belgian Congo. Named from the locality. [M.A. **12** 568.]

Limaite. J. M. Cotelo Neiva, 1954. Mem. Notíc. Mus. Laborat. Min. Geol. Univ. Coimbra, no. 36, pp. 17, 20 (limaíte), p. 55 (limaïte), p. 59 (limaite); Estudos, Notas e Trab. Serv. Fomento Mineiro [1954], vol. 9, p. 111. Stanniferous variety of gahnite, $(Zn,Sn)Al_2O_4$ with Zn:Sn = 3:1. Octahedra in pegmatite from near Ponte do Lima, Portugal. Named from the locality. Previously mentioned and later described, without name, in Bull. Soc. Franç. Min. Crist., 1952, vol. 75, p. xxxvi; 1955, vol. 78, p. 97. [M.A. **12**–572.]

Lime-dravite. F. H. Pough, 1953. *See* Soda-dravite.

Lime-iron-olivine. R. W. Nurse and H. G. Midgley, 1953. Journ. Iron & Steel Inst., vol. 174, p. 124 (lime-iron olivine, $CaFeSiO_4$). Quoted from N. L. Bowen, J. F. Schairer, and E. Posnjak, Amer. Journ. Sci., 1933, ser. 5, vol. 25, p. 275; vol. 26, p. 195, who, however, have only the form Ca-Fe olivine for artificial material. [M.A. 5–252, 454, **12**–197.]

Lipscombite. M. A. Gheith, 1953. Amer. Min., vol. 38, p. 612 (pronounced lips-kum-ite). Artificially produced tetragonal iron phosphate approximating to $Fe''Fe_2'''(PO_4)_2(OH)_2$. To replace the name

iron-lazulite (19th List). Named after Professor William Nunn Lipscomb (1909–) of the University of Minnesota. *See* Barbosalite and Ferro-ferri-lazulite. [M.A. **12** 238.]

Lithian-muscovite. A. A. Levinson, 1952. Progr. & Abstr. Min. Soc. Amer., p. 30 (lithium muscovite); Amer. Min., 1953, vol. 38, p. 88 (lithian muscovite), p. 93 (lithian-muscovite). A structural variation in the muscovite polymorphs containing Li_2O 3·4–4·0 %. Distinct from lithium-muscovite (15th List). [M.A. **12**–98.]

Lithia–tourmaline. R. R. Riggs, 1888. Amer. Journ. Sci., ser. 3 vol. 35, p. 50 (Lithia tourmaline). P. Quensel, Geol. För. Förh. Stockholm, 1939, vol. 61, p. 63 (lithium tourmaline), p. 76 (Li-tourmaline). J. Sekanina, Věstník Stat. Geol. Úst. Česk., 1946, p. 302 (lithné turmaliny *pl.*), p. 311 (tourmalines lithiques). [M.A. **7**–335, **10**–119.]

Liversite. C. F. Barb, Quart. Colorado Sch. Mines, 1944, vol. 39, p. 18 ("liversite"). Local name for elaterite from Strawberry river, Utah.

Livesite. K. Carr, R. W. Grimshaw, and A. L. Roberts, 1951. Trans. Brit. Ceramic Soc., vol. 51, p. 339 (name in table without description). A constituent of Yorkshire fireclay presumably intermediate between kaolinite and halloysite. R. E. Grim, in discussion at symposium, Problems of clay and laterite genesis, Amer. Inst. Mining & Metall. Engineers, New York, 1952, p. 221 (levisite); Clay mineralogy, New York & London, 1953, p. 49 (levisite). Named after Sir George Thomas Livesey (1834 1908), in whose memory the Livesey professorship of coal gas and fuel was founded in 1910 in Leeds University. [M.A. **12**–184, 212; cf. Min. Mag. **30**–139.]

Lodochnikovite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2, vol. 82, p. 317 (Лодочниковит). Al,Mg,Ca,Fe oxide, monoclinic, bluish-green, in skarn with spinel, &c. Named after Vladimir (formerly Wartan) N. Lodochnikov, Владимир Н. Лодочников (1887–1942), Petrologist on the Geological Survey of Russia. [M.A. **12**-352.]

Lupikkite. M. K. Palmunen, 1939. [Geol. Toimikunta, Geoteknillisiä julkaisuja, no. 44.] M. Saksela, Bull. Comm. Géol. Finlande, 1951, no. 154, p. 191 (Lupikkit). A mixture of cubanite, pyrrhotine, chalcopyrite, and blende, from Lupikko, Pitkärata, Finland. [M.A. **12**-70.]

Maakite. B. K. Polenov, 1910. Protok. Obshch. Estestv. Kazan. Univ., for 1908-9, no. 246, p. 8 (маакит). J. Paclt, Neues Jahrb. Min., Monatshefte, 1953, p. 189 (Maakit). Synonym of hydrohalite ($NaCl.2H_2O$), cryohalite (Kryohalit), and bihydrate (a chemical term). Named after Richard Karlovich Maak, Р. К. Маакъ (1825–87), who in 1850 collected material from a salt lake in Yakutsk, Siberia. *See* Cryohalite. [M.A. **12**–239.]

Magnalumoid. Zeits. Geologie, Berlin, 1952, vol. 1, p. 361. Abbreviation of magnalumoxide (19th List).

Magnesian chamosite. F. A. Bannister and W. F. Whittard, 1945. Min. Mag., vol. 27, p. 99 (Magnesian chamosite). Variety of chamosite containing MgO 8·75 %.

—— H. S. Yoder, 1952. Amer. Journ. Sci., Bowen volume, p. 588 (Magnesian chamosite), p. 597 (magnesian-chamosite). Artifically produced $3MgO.Al_2O_3.2SiO_2$, corresponding to chamosite with MgO in place of FeO. [M.A. **12**–83.]

Magnesioarfvedsonite. W. E. Tröger, 1952. Tabellen opt. Bestim. gesteinsbild. Minerale, p. 146 (Magnesioarfvedsonit). Variety of arfvedsonite.

Magnesio-magnetite. (Author?). J. D. Dana, Min., 5th edit., 1868, p. 150 (Magnesian magnetite). A. E. Fersman and O. M. Shubnikova, Geochem. Min. Companion, Moscow, 1937, p. 167 (Магнезиомагнетит). Variety of magnetite containing some MgO.

Magnesium-kaolinite. N. E. Efremov, 1954. Bull. Geol. Soc. Amer., [1955], vol. 65, no. 12 (for 1954), p. 1374 (magnesium kaolinite). A kaolinite-like mineral with the composition $2MgO.2Al_2O_3.3SiO_2.4H_2O$, one SiO_2 being replaced by 2MgO. [M.A. **12** 570.]

Magnesium-morenosite. C. O. Hutton, 1947. Amer. Min., vol. 32, p. 559 (magnesian morenosite). Morenosite containing some magnesium, $(Ni,Mg)SO_4.7H_2O$. *See* Nickel-epsomite.

Magnesium-sericite. H. Minato and Y. Takano, 1952. Papers College Gen. Educ. Univ. Tokyo, vol. 2, p. 196 (magnesium sericite). A sericitic clay from Japan containing MgO 2·74, Fe_2O_3 0·46, FeO 1·57 %. *See* Iron-sericite. [M.A. **12**–221.]

Magnesium-vermiculite. G. F. Walker, 1950. Nature, London, vol. 166, p. 695 (Magnesium-vermiculite). A. McL. Mathieson and G. F. Walker, Amer. Min., 1954, vol. 39, p. 231 (Magnesium-vermiculite, Mg-vermiculite). Regarded as a clay-mineral occurring in soils and analogous to montmorillonite. [M.A. **12**–437.]

Magnymontmorillonite. I. D. Sedletzky, 1951. Priroda, Acad. Sci. USSR, vol. 40, no. 2, p. 61 (Магниймонтмориллонит). Abstract in Zentralblatt Min., Teil I, 1953, for 1952, p. 246 (Magnijmontmorillonit). Synonym of Magnesium-montmorillonite (16th List). [M.A. **12**–239.]

Mangan-crocidolite. P. de Wijkerslooth, 1943. Madan Tetkik ve Arama Enstitüsü Mecmuası, Ankara, vol. 8, p. 99 (manganez krokidolit, Turkish), p. 108 (Mangankrokidolit, German). Variety of crocidolite containing some manganese, from manganese ore deposits in Anatolia. [M.A. **9**–241.]

Manganese-hörnesite. O. Gabrielson, 1951. Arkiv Min. Geol. Stockholm, vol. 1, p. 333 (manganese-hoernesite). $(Mn,Mg)_3(AsO_4)_2.8H_2O$, monoclinic, isomorphous with hörnesite $Mg_3(AsO_4)_2.8H_2O$, and bobierrite $Mg_3(PO_4)_2.8H_2O$. From Långban, Sweden. Named after Moriz Hörnes (1815–1868) of Vienna. [M.A. **12**–130.]

Manganpyrosmalite. C. Frondel and L. H. Bauer, 1953. Amer. Min., vol. 38, p. 755. Variety of pyrosmalite with Mn in excess of Fe. [M.A. **12**–236.]

Mangan-rockbridgeite. M. L. Lindberg, 1949. Amer. Min., vol. 34, p. 341 (manganoan rockbridgeite); M.A. 1950, **11**–8 (manganiferous rockbridgeite); Hintze, Min., 1954, Ergbd. 2, p. 242 (Mangan-Rockbridgeit). A dufrenite-like mineral $(Fe'',Mn'')Fe_4'''(PO_4)_3(OH)_5$, intermediate between frondelite $Mn''Fe_4'''(PO_4)_3(OH)_5$ and rockbridgeite $Fe''Fe_4'''(PO_4)_3(OH)_5$, (19th List, where these formulae are incorrectly given).

Mangan-sicklerite. Dana, Min., 7th edit., 1951, vol. 2, p. 672; Hintze Min., 1954, Ergbd. 2, p. 243 (Mangansicklerit). Variant of Manganese-sicklerite (16th List), Mangani-sicklerite (19th List).

Manganzoisit. Hintze, Min., 1954, Ergbd. 2, p. 244. Variant of Manganese-zoisite (14th List).

Metabayleyite. T. W. Stern and A. D. Weeks, 1952. Amer. Min., vol. 37, p. 1060. Artificially dehydrated bayleyite (18th List). [M.A. **12**–281.]

Metatyuyamunite. A. D. Weeks, M. E. Thompson, and R. B. Thompson, 1953. Progr. & Abstr. Min. Soc. Amer., p. 43; Amer. Min., 1954, vol. 39, p. 348 (abstract). A. D. Weeks and M. E. Thompson [Bull. U.S. Geol. Surv., 1954, no. 1009 B, p. 37]; Amer. Min., 1954, vol. 39, p. 1037 (abstract). A lower hydrate 5–7H_2O of tyuyamanunite $Ca(UO_2)(VO_4)_2.9H_2O$ (6th List). [M.A. **12**–511, 566.]

Mikheevite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2, vol. 82, p. 317 (Михеевит). $K_2Ca_4(SO_4)_5.H_2O$, triclinic, in salt deposits. Named after V. I. Mikheev, В. И. Михеев. [M.A. **12**-352.]

Mikroantigorit. Hintze, Min., Ergbd. 2, p. 264. Variant of Microantigorite (13th List).

Mirzaanite. L. D. Melikadze and T. A. Eliava, 1948. [Kolloid. Zhurnal, Voronezh, vol. 10, p. 115.] Abstracts in Amer. Chem. Abstr., 1949, vol. 43, col. 5350 (mirzaanite); Brit. Chem. Abstr., 1949, B II, col. 356; Bull. Soc. Franç. Min. Crist., 1954, vol. 77, p. 1270 (mirsaanite). An elastic bitumen, variety of elaterite, from the Mirzaani (Мирзаани) oil-field, Georgia, Transcaucasia. [M.A. **12**–511.]

Mohelnite. R. Dvořák, 1943. [Příroda, Brno, vol. 35, p. 190.] J. Paclt, Neues Jahrb. Min., Monatshefte, 1953, p. 189 (Mohelnit). An incompletely described chlorite in the serpentine of Mohelno, Moravia, perhaps identical with clinochlore or moravite (4th List). Named from the locality. [M.A. **12**–240.]

Montmorillonoids. D. M. C. MacEwan, 1951. X-ray identification and mineral structures of clay minerals, Min. Soc., London, p. 86; Clay Min. Bull., 1951, vol. 1, p. 195. Group name for minerals related to the original montmorillonite from Montmorillon, France. [M.A. **11**–253.]

Moraesite. M. L. Lindberg, W. T. Pecora, and A. L. de M. Barbosa, 1953. Amer. Min., vol. 38, p. 1126. Hydrous beryllium phosphate, $Be_2PO_4(OH).4H_2O$, as white fibrous masses, monoclinic; from Sapucaia pegmatite mine, Brazil. Named after Dr. Luciano Jacques de Moraes, Brazilian geologist. [M.A. **12**–301.]

Murdochite. J. J. Fahey, 1953. Progr. & Abstr. Min. Soc. Amer., p. 21; Amer. Min., 1954, vol. 39, p. 327. C. L. Christ and J. R. Clark, ibid., pp. 15, 321. Cu_6PbO_8 as tiny black octahedra with NaCl structure. Named after Prof. Joseph Murdoch (1890–) of the University of California at Los Angeles. [M.A. **12** 304.]

Mysite. H. Moissan, 1905. Traité de chemie minérale, vol. 4, p. 372. Error for misy. (On the same page the names of other iron sulphates are incorrectly spelt.)

Natro-alumobiotite. D. P. Serdyuchenko, 1954. Doklady Acad. Sci. USSR, vol. 97, p. 317 (натровый алюмобиотит). A composition variety of biotite containing Al_2O_3 22·85, Na_2O 2·76 %. [M.A. **12**–535.]

Natro-ferrophlogopite. D. P. Serdyuchenko, 1954. Doklady Acad. Sci. USSR, vol. 97, p. 317 (натровый феррофлогопит). A composition variety of phlogopite containing FeO 15·56, Na_2O 3·18 %. [M.A. **12**–535.]

Navajoite. A. D. Weeks, M. E. Thompson, and A. M. Sherwood, 1954. Science (Amer. Assoc. Adv. Sci.), vol. 119, p. 326; Amer. Min., 1955, vol. 40, p. 207. $V_2O_5.3H_2O$, as brown fibres, probably monoclinic, from Arizona. Named after the Navajo Indians. [M.A. **12**–408, 567.]

Nenadkevichite. M. V. Kuzmenko and M. E. Kazakova, 1955. Doklady Acad. Sci. USSR, vol. 100, p. 1159 (Ненадкевичит). Niobo-titano-silicate $(Na,Ca)(Nb,Ti)Si_2O_7.2H_2O$, orthorhombic, in alkalic rock from Kola. Named after Konstantin Avtonomovich Nenadkevich, Константин Автономович Ненадкевич, Russian mineralogist and geochemist. [M.A. **12**–569.]

Nickel-epsomite. C. O. Hutton, 1947. Amer. Min., vol. 32, p. 553 (nickelian epsomite); Hintze, Min., 1954, Ergbd. 2, p. 284 (Nickelepsomit). A mineral (NiO 12·22, MgO 9·81 %) of the epsomite

group, approaching morenosite in composition. *See* Magnesium-morenosite. [M.A. **10**–388.]

Nickel-magnetite. C. Doelter, 1926. Mineralchem., vol. 3, pt. 2, p. 666 (Nickelmagnetit). Synonym of trevorite (10th List).

Nigerite. R. Jacobson and J. S. Webb, 1946. Bull. Geol. Surv. Nigeria, no. 17, p. 27. Earlier reference than that given in 18th List.

Nitrate-hydrotalcite. D. M. Roy, R. Roy, and E. F. Osborn, 1953. Amer. Journ. Sci., vol. 251, p. 355 (nitrate-hydrotalcite). Artificially produced $Mg_6Al_2(N_2O_5)(OH)_{16}.4H_2O$, analogous to hydrotalcite ('carbonate-hydrotalcite') with N_2O_5 in place of CO_2. [M.A. **12**–196.]

Noǧisawaite. Z. Harada, Journ. Fac. Sci. Hokkaido Univ., 1954, sect. 4, vol. 8, p. 322 [M.A. **12**–477]. Another spelling of nogizawalite (19th List), perhaps a variety of beckelite. [M.A. **11**–311.]

Ocrite. H. von Philipsborn, 1953. Tafeln zum Bestimmen der Mineralien, Stuttgart, p. xi (Bi-ocrit, Mo-ocrit), p. 72 (Wismutocker, Molybdänocker). Collective name for powdery ochres. [M.A. **12**–297.]

Ordoñezite. G. Switzer and W. F. Foshag, 1953. Progr. & Abstr. Min. Soc. Amer., p. 40; Amer. Min., 1954, vol. 39, p. 346; 1955, vol. 40, p. 64. Zinc antimonate, $ZnSb_2O_6$, tetragonal, brown crystals in tin ore from Guanajuato, Mexico. Named after the late Ezequiel Ordoñez, Mexican geologist. [M.A. **12**–303, 512.]

Ortho-antigorite. G. W. Brindley and O. von Knorring, 1954. Amer. Min., vol. 39, p. 794 (ortho-antigorite). A variety of antigorite based on an ortho-hexagonal cell; from Unst, Shetland. [M.A. **12**-463.]

Ortho-chevkinite. S. Bonatti and G. Gottardi, 1953. Rend. Soc. Min. Ital., vol. 9, p. 242 (orto-chevkinite). Orthorhombic chevkinite from Madagascar [M.A. **1**–376, **2** 269], as distinct from clino-chevkinite (q.v.). [M.A. **12**–240, 498.]

Ortho-chrysotile. E. J. W. Whittaker, 1951. *See* Clino-chrysotile.

Osumilite. A. Miyashiro, 1953. Proc. Japan Acad., vol. 29, p. 321 (osumilite). A mineral resembling cordierite, but hexagonal, $(K,Na,Ca)(Mg,Fe'')_2(Al,Fe''',Fe'')_3(Si,Al)_{12}O_{30}.H_2O$, in volcanic rock from prov. Ôsumi, Japan. Named from the locality. [M.A. **12**–304, 616.]

Oxytschildrenit. K. F. Chudoba, Hintze, Min., 1954, Ergbd. 2, p. 294 (Oxychildrenit, richtiger Oxytschildrenit?). Superfluous synonym of oxychildrenite (19th List). Named after John George Children (1777–1852) of the British Museum.

Palermoite. M. E. Mrose, 1952. Progr. & Abstr. Min. Soc. Amer., p. 35; Bull. Geol. Soc. Amer., vol. 63, p. 1283; Amer. Min., 1953, vol. 38, p. 354 (abstract). $(Li,Na)_4SrAl_9(PO_4)_8(OH)_9$, orthorhombic prisms in

pegmatite from Palermo mine, North Groton, New Hampshire. Named from the locality. [M.A. **12**–131.]

Palladite. V. I. Vernadsky, 1914. Essay descrip. Min., St. Petersburg, pp. 128, 232, 262 (палладит). Variant of palladinite, PdO (C. U. Shepard 1857).

Pallite. L. Capdecomme and R. Pulou, 1954. Compt. Rend. Acad. Sci. Paris, vol. 239, p. 288. A hypothetical type of Ca-Al phosphate in phosphorites from Senegal. Derivation of name not given. [M.A. **12**–440.]

Parahalloysite. D. P. Serdyuchenko, 1953. Problems (вопросы) Petr. Min. (Acad. Sci. USSR), vol. 2, p. 100 (парагаллуазит). Clays similar to halloysite in composition but to silica-poor montmorillonite in structure. Mg-, Fe-Mg-, and Fe-Cr- varieties are distinguished. [M.A. **12**–513.]

Parasymplesite. T. Ito, H. Minato, and K. Sakurai, 1954. Proc. Japan Acad., vol. 30, p. 318. Monoclinic $Fe_3(AsO_4)_2.8H_2O$, dimorphous with triclinic symplesite; from Japan. [M.A. **12**–412.]

Pavonite. E. W. Nuffield, 1953. Progr. & Abstr. Min. Soc. Amer., p. 33; Amer. Min., 1954, vol. 39, pp. 338, 409. Contrib. Canadian Min., 1954, vol. 5, pt. 6. $AgBi_3S_5$, monoclinic, for a Bolivian mineral previously referred to alaskaite and to benjaminite. Named from the Latin pavo, pavonis, peacock, in honour of Prof. Martin Alfred Peacock (1898–1950) of the University of Toronto. [M.A. **12**–304, 410.]

Peligotite. V. G. Melkov, 1942. Mém. Soc. Russ. Min., vol. 71, p. 9 (пелигоит, *sic*), p. 11 (peligotite). A secondary uranium sulphate, $CuO.2UO_3.2SO_3.3H_2O.aq$', from Tadzhikstan. Named after Eugène Melchior Péligot (1811 90), French chemist, who isolated metallic uranium in 1840. [Not sufficiently distinguished from johannite.] [M.A. **12**-461.]

Pitankite. (Author?). A. K. Boldyrev, Kurs opisatelnoi min., Leningrad, 1926, vol. 1, p. 259 (питанкит, index only); A. E. Fersman and O. M. Shubnikova, Sputnik geochim. min., Moscow, 1937, p. 187. $2(Ag,Pb,Cu)S.Bi_2S_3$'. (Locality?, derivation?)

Polialite. Italian spelling of polyhalite.

Poliophane. F. Machatschki, 1953. Spezielle Mineralogie, Wien, p. 226 (Fahle, Poliophane, *pl.*). Group name for fahlore (grey copper) and bournonite. Named from πολιός, grey.

Poly-, prefix in some 30 mineral names (polybasite, polycrase, polyhalite, polyaugite, &c.) also in the terms polymorph, polymer, polysynthetic twinning, polyhedron, &c. It has now been extended with other significations, giving rise to polyonymous complexities.

Polybrookite. F. Machatschki, Spezielle Mineralogie, Wien, 1953, p. 319 (Polybrookite, *pl.*), p. 371 (Polybrookit). Columbite and tantalite isotypic with brookite. [M.A. **12**–232.]

Polycrystal. [G. Donnay, Amer. Cryst. Assoc., June 1953], G. Donnay and J. D. H. Donnay, Amer. Min. 1953, vol. 38, p. 941. An apparently single crystal consisting of a regular intergrowth of different minerals. [M.A. **12**–329.]

Polygorskite. C. E. Marshall, Colloid chemistry of silicate minerals, New York, 1949, p. 54. Error for palygorskite.

Polyhydrate. V. I. Popov and A. L. Vorobiev, 1947. Mém. Soc. Russ. Min., vol. 76, p. 268 (полугидрат). Hintze, Min., 1954, Ergbd. 2, p. 317 (Polyhydrat). Error for hemi(polu)hydrate $CaSO_4.\frac{1}{2}H_2O$. [M.A. **11**–366.] *See* Miltonite (19th List), Bassanite (6th List).

Polymigmite. F. Machatschki, 1953, ibid., p. 319 (Polymigmit). Error for polymignite (*μιγνύω*, to mix, not *μίγμα*, a mixture).

Polymineralic rocks. F. Machatschki, 1953, ibid., p. 1 (Polymineral Gesteine), as distinct from monomineralic rocks.

Polyophane. F. Machatschki, ibid., p. 371. Error for poliophane (q.v.).

Polyphant stone. Greyish-green potstone flecked with white and brown, from Polyphant, Cornwall, used as an ornamental stone in churches since Norman times.

Polyplatinum. F. Machatschki, 1953, ibid., p. 302 (Polyplatin). Platinum containing Fe, Ir, Os, Rh, Pd.

Polyquartz. F. Machatschki, 1953, ibid., p. 82 (Polyquarze, *pl.*), p. 371 (Polyquarz). Compounds $AlPO_4$ (berlinite), $AlAsO_4$, $FePO_4$, BPO_4, isotypic with quartz ($SiSiO_4$). (The corresponding polymorphs have been named Al-phosphorotridymite and Al-phosphorocristobalite, R. L. Manly, 1950, M.A. **11**–180.)

Polyrutile. F. Machatschki, 1953, ibid., p. 118 (Polyrutile, *pl.*), p. 371 (Polyrutil). Tapiolite and mossite isotypic with rutile. (Compare polyrutiles and trirutiles of V. M. Goldschmidt, 1923, M.A. **3**–182.)

Polywurtzite. F. Machatschki, 1953, ibid., p. 371 (Polywurtzit), p. 305 (Polywurtzite, *pl.*). Hexagonal polymorphs of ZnS.

Potassium-bentonite. C. E. Weaver and T. F. Bates, 1951. Bull. Geol. Soc. Amer., vol. 62, p. 1488 (potassium bentonites, K-bentonites); C. E. Weaver, Amer. Min., 1953, vol. 38, p. 698. A montmorillonite clay containing potassium, from Ordovician limestone, Pennsylvania. Same as metabentonite, 14th List.

Potassium-melilite. R. W. Nurse and H. G. Midgley, 1953. Journ. Iron & Steel Inst., vol. 174, p. 121 (Potassium-melilite). Hypothetical

end-member, $KCaAlSi_2O_7$, of the melilite series. Present in small amount in natural melilite and up to 20 % in solid solution in artificial gehlenite. [M.A. **12**–197.]

Potassium-priderite. K. Norrish, 1951. Min. Mag., vol. 29, p. 500 (K-priderite). Hintze, Min., 1954, Ergbd. 2, p. 31 (Kaliumpriderit), p. 189 (Kalium-Priderit). *See* Barium-priderite.

Prokoenenite. W. Berdesinski, 1952. Neues Jahrb. Min., Abh., vol. 84, p. 147 (Prokoenenit). An early stage in the artificial production of koenenite. [M.A. **12**–77.]

Protowollastonite. T. Ito, 1950. X-ray studies on polymorphism. Tokyo, 1950, p. 105 (protowollastonite). Hypothetical monoclinic wollastonite, which by different modes of twinning has given rise to monoclinic parawollastonite (14th List) and the more common form of triclinic wollastonite. [M.A. **11**–308.]

Pseudo-willemite. G. Sabatier, 1952. Bull. Soc. Franç. Min. Crist., vol. 75, p. 521 (pseudo-willémite). Cubic modification of Zn_2SiO_4, artificially produced. [M.A. **12**–81.]

Rabbittite. M. E. Thompson, A. D. Weeks, and A. M. Sherwood, 1954. [Trace Elements Rep. U.S. Geol. Surv., no. 405, p. —.] A. D. Weeks and M. E. Thompson. [Bull. U.S. Geol. Surv., 1954, no. 1009–B, p. —.] Abstract in Amer. Min., 1954, vol. 39, p. 1037 (rabbitite). Amer. Min., 1955, vol. 40, p. 201 (rabbittite). Uranyl carbonate with Ca and Mg, $Ca_3Mg_2(UO_2)_2(CO_3)_6(OH)_4$. Monoclinic, minute greenish-yellow needles as an efflorescence on mine walls in Utah. Named after John Charles Rabbitt (1907–) of the U.S. Geological Survey. [M.A. **12**–511, 566–7.]

Reedmergnerite. C. Milton, J. M. Axelrod, and F. S. Grimaldi, 1954. Bull. Geol. Soc. Amer. [1955], vol. 65, no. 12 (for 1954), p. 1286; Amer. Min., 1955, vol. 40, p. 326 (abstract). $Na_2O.B_2O_3.6SiO_2$, triclinic, small colourless crystals from oil wells in Utah. Named after Frank S. Reed and John L. Mergner, technicians of the United States Geological Survey. [M.A. **12**–511.]

Ribeirite. W. Florencio, 1952. Anais Acad. Brasil. Cienc., vol. 24, p. 259 (ribeirita). An altered zircon containing yttrium earths 7·45 %, etc., from Brazil. Named after Prof. Joaquim Costa Ribeiro. [M.A. **12**–505.]

Röntgenite. G. Donnay, 1953. Amer. Min., vol. 38, p. 868 (roentgenite). Minute wax-yellow to brown, trigonal pyramidal crystals, intergrown with synchysite, parisite, and bastnäsite, from Narsarsuk, Greenland. From X-ray and optical data the composition is deduced as $Ce_2FCO_3.2CaCO_3$. Named after Wilhelm Conrad von Röntgen (1845–1923) of München, discoverer of X-rays (Röntgen rays). [M.A. **12**–238, 329.]

Rutilohematite. A. F. Buddington, J. Fahey, and A. Vlisidis, 1953. Progr. & Abstr. Min. Soc. Amer., 1953, p. 13; Amer. Min., 1954, vol. 39 p. 319 (rutilohematite). The most oxidized facies of Fe-Ti oxides. *See* Ilmenomagnetite.

Sahamalite. H. W. Jaffe, R. Meyrowitz, and H. T. Evans, 1953 Amer. Min., vol. 38, p. 741. $(Mg,Fe)(Ce,La,Nd)_2(CO_3)_4$, monoclinic, as minute colourless crystals from the alteration of bastnäsite. From Mountain Pass, San Bernardino Co., California. Named after Professor Thure Georg Sahama (1910–) of Helsinki, Finland. [M.A. **12**–237.]

Schilkinit. *See* Chilkinite.

Shcherbakovite. E. M. Eskova and M. E. Kazakova, 1954. Doklady Acad. Sci. USSR, vol. 99, p. 837 (щербаковит). Silicate and titanoniobate $Na(K,Ba)_2(Ti,Nb)_2(Si_2O_7)_2$, monoclinic. Named after D. I. Shcherbakov, Д. И. Щербаков. [M.A. **12**–569.]

Shubnikovite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2, vol. 82, p. 317 (Шубниковит). Hydrous chloro-arsenate of Cu, Ca, and K, orthorhombic ?, blue plates. Named after Aleksei Vasilievich Shubnikov, Алексей Васильевич Шубников (1887–), Director of the Crystallographic Institute, Acad. Sci., Moscow. [M.A. **12**–352.]

Silikatsulfatapatit. Synonym of wilkeite. *See* Bleiapatit.

Skorzalith. W. E. Tröger, 1952. Tabellen opt. Bestim. gesteinsbild. Minerale, p. 147. German form of scorzalite (18th List), named after E. P. Scorza.

Soda-adularia, Soda-sanidine. A. N. Winchell, 1927. Optical mineralogy, part II, 2nd edit., pp. 318, 322 (soda-adularia, soda-sanidine); 4th edit., 1951, p. 302 (sodian adularia, sodian sanidine). Varieties of soda-orthoclase (q.v.). *See* Natronsanidine (5th List).

Soda-augite. K. Yagi, 1953. Bull. Geol. Soc. Amer., vol. 64, p. 781. Augite containing Na_2O up to 1·7 %, intermediate between augite and aegirine-augite, as zoned crystals and single crystals.

Soda-dravite. F. H. Pough, 1953. Field guide to rocks and minerals, Boston, p. 280 (Soda-dravite). $NaMg_3B_3Al_3(Al_3Si_6O_{27})(OH)_4$, a brown variety of tourmaline. Similarly, lime-dravite, $CaMg_3B_3Al_3(Al_3Si_6O_{27})(O,OH)_4$, a white variety.

Soda-orthoclase. J. P. Iddings, 1906. Rock minerals, pp. 203, 232. 'Those apparently monosymmetric feldspars with notable amount of soda may be called soda-orthoclase. . . . When the soda equals or exceeds the potash the crystals exhibit triclinic symmetry and are soda-microcline'. *See* Soda-microcline = Natronmikroklin = anorthoclase (2nd List).

Sodium-melilite. R. W. Nurse and H. G. Midgley, 1953. Journ. ron & Steel Inst., vol. 174, p. 121. Artificially produced end-member, $NaCaAlSi_2O_7$, of the melilite series. Distinct from the hypothetical end-ember soda-melilite, $Na_2Si_3O_7$ (12th List). [M.A. **12**–197.]

Stepanovite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2, ol. 82, p. 317 (Степановит). Oxalate $NaMgFe'''(C_2O_4)_3.8\text{-}9H_2O$, igonal, yellowish-green, granular, in coal. [M.A. **12**–353.]

Strontian-apatite. E. S. Larsen, M. H. Fletcher, and E. A. Cisney, 052. Amer. Min., vol. 37, p. 656 (Strontian apatite, Strontian fluor-patite, Strontian hydroxylapatite). Variety of apatite containing rO 11·6 %. [M.A. **12**–225.]

Suanite. T. Watanabe, 1952. [Geology and mineral resources of the ar East]; Min. Journ. (Min. Soc. Japan), 1953, vol. 1, p. 54. Pyro-orate of magnesium, $Mg_2B_2O_5$, monoclinic, from Suan, Korea. Named om the locality. [M.A. **12**–411.]

Szamozyt. Polish spelling of chamosite. [M.A. **12**–350.]

Tavorite. M. L. Lindberg and W. T. Pecora, 1954. Science (Amer. ssoc. Adv. Sci.), vol. 119, p. 739. Hydrous lithium ferric phosphate, $LiFe(PO_4)(OH)$, as yellow fine-grained aggregates from Brazil. Named ter Prof. Elysiario Tavora, University of Brazil, Rio de Janeiro. [M.A. **12**–408.]

Tchinglusuite, Tschinglusuit. French (Bull. Soc. Franç. Min. ist., 1951, vol. 74, p. 191) and German (Hintze, Min., 1954, Ergbd. 2, 399) transliterations of чинглусуит, chinglusuite (15th List).

Tellurobismutite. M. N. Short, 1931. Bull. U.S. Geol. Surv., no. 25, p. 73 (telluro-bismutite). Synonym of tellurobismuthite (9th List) Bi_2Te_3, as distinct from tetradymite (Bi_2Te_2S). The earlier names ellurwismuth (J. J. Berzelius, 1823) and tellurbismuth (D. M. Balch, 363) covered both. [M.A. **8**-8, 109, 183, 311; **9**–213, 262; **10** 126, 26.]

Tertschite. H. Meixner, 1953. Fortschr. Min., vol. 31 (for 1952), 39 (Tertschit). Hydrous calcium borate, $Ca_4B_{10}O_{19}.20\text{-}21H_2O$, finely rous, probably monoclinic, from Turkey. Named after Prof. Her-ann Tersch (1880–) of Vienna. [M.A. **12**–353.]

Umohoite. P. F. Kerr and G. P. Brophy, 1953. Rocks & Minerals, eekskill, N.Y., vol. 28, p. 480. Hydrous molybdate of uranium, black, ky, hexagonal, from Utah. Named from the composition. [M.A. 2–239.]

Uranoflorescite. H. von Philipsborn, 1953. Tafeln zum Bestimmen r Minerale, Stuttgart, pp. xi, 74 (Uranoflorescit, Uranblüte). A llective name for efflorescences of secondary uranium minerals.

Väyrynenite. A. Volborth and E. Stradner, 1954. Anz. Math. naturwiss. Kl. Österreich. Akad. Wiss., Wien, vol. 92, p. 21. A. Volborth Ann. Acad. Sci. Fennicae, 1954, ser. A, III Geol. Geogr., no. 39, p. (Väyrynenit). $MnBe(PO_4)(OH,F?)$, similar to herderite with Mn in pla of Ca. Monoclinic, rose-red, in Li-pegmatite from Finland. Named afte Dr. Heikki Väyrynen, professor of mineralogy and geology in t Technical Highschool, Helsinki. [M.A. **12**-354, 568.]

Vladimirite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2 vol. 82, p. 317 (Владимирит). $3CaO.As_2O_5.4H_2O$, monoclinic?, colou less radiating needles. [M.A. **12**–352.]

Volkovite. E. I. Nefedov, 1953. Mém. Soc. Russ. Min., ser. 2, vol. 8 p. 317 (Волковит). Hydrous borate of Sr and K, monoclinic, Inder sa deposits, Kazakhstan. [M.A. **12**–352.]

Wairakite. A. Steiner, 1955. Min. Mag., vol. 30, p. 691. D. S Coombs, ibid., p. 699. A zeolite, $CaO.Al_2O_3.4SiO_2.2H_2O$, the calcium analogue of analcime, but optically biaxial, monoclinic (pseudo-cubic From hot springs at Wairaki, New Zealand. Named from the locality *See* Calcium-analcime.

Wilkinite. S. D. Wells, 1920. Paper, New York, vol. 27, no. 4, p. 1 (Wilkinite); P. F. Kerr and P. K. Hamilton, Glossary of clay minera names, 1949, p. 68 (Wilkonite) [M.A. **11**–169.] Trade-name for a col loidal bentonite ('jelly rock') used for loading book paper.

Woodruffite. C. Frondel, 1953. Amer. Min., vol. 38, p. 761. psilomelane-like mineral with the composition $2(Zn,Mn)O.5MnO_2$ $4H_2O$, from Sterling Hill, New Jersey. Named after the late Samue Woodruff, for many years a miner with the New Jersey Zinc Compan and a keen collector of minerals. [M.A. **12**–237.]

Yttrianite. J. Takubo et al., 1953. Journ. Geol. Soc. Japan, vol. 5 p. 58. Error for yttrialite. [M.A. **12**–279.]

Yugawaralite. K. Sakurai and A. Hayashi, 1952. [Sci. Re Yokohama Nat. Univ., sect. 2, no. 1, p. 60]; abstract in Amer. Min 1953, vol. 38, p. 426. A monoclinic zeolite, '$Ca_4Al_7Si_{20}O_{54}.14H_2O$', i altered andesite tuffs near the Yugawara hot spring, Kanagawa, Japa Named from the locality. [M.A. **12**–133.]

Zinc-högbomite. V. A. Moleva and V. S. Myasnikov, 1952. Doklad Acad. Sci. USSR, vol. 83, p. 733 (цинк-хёгбомит). Variety of högbomit containing ZnO 11·12 %. [M.A. **12**–13.]

Zinc-rockbridgeite. M. L. Lindberg and C. Frondel, 1950. Amer Min., vol. 35, p. 1028 (Zincian rockbridgeite). H. Strunz, Neues Jahrb

Min., Abh., 1952, vol. 84, p. 89 (Zinkrockbridgeit). A zinciferous variety of rockbridgeite (ZnO 5·20 %), from Portugal and Bavaria. [M.A. **11**–187.]

Zirkoneuxenite. F. Machatschki, 1953. Spezielle Mineralogie, Wien, p. 319 (Zirkoneuxenit = Polymigmit, q.v.). Synonym of polymignite.

Zonotlite. E. S. Larsen and H. Berman, 1934. Bull. U.S. Geol. Surv., no. 848 (2nd edit.), pp. 108, 266. Error for xonotlite, from Tetela de Xonotla (= Tetela del Oro), Puebla, Mexico.

SYSTEMATIC CLASSIFICATION OF NEW MINERALS[1]

Suphosalts

Arsenosulvanite, $Cu_3(As,V)S_4$, VII.
Pavonite, $AgBi_3S_5$, II.

Oxides

Murdochite, Cu_6PbO_8, VII.

Hydroxides

Navajoite, $V_2O_5.3H_2O$, II?
Woodruffite, $2(Zn,Mn)O.5nO_2.4H_2O$.

Carbonates

Huntite, $Mg_3Ca(CO_3)_4$, III.
Eitelite, $Na_2Mg(CO_3)_2$, VI.
Callaghanite, $Cu_4Mg_4Ca(OH)_{14}(CO_3)_2.2H_2O$, II.
Burbankite, $(Ca,Sr,Ba,Ce,Na)_6(CO_3)_5$, VI.
Calkinsite, $(La,Ce,\&c.)_2(CO_3)_2.4H_2O$, III.
Sahamalite, $(Mg,Fe)(Ce,\&c.)_2(CO_3)_4$, II.
Röntgenite, $3CeFCO_3.2CaCO_3$, V.
Rabbittite, $Ca_3Mg_2(UO_2)_2(CO_3)_6(OH)_4$, II.

Nitrate

Likasite, $Cu_{12}(NO_3)_4(PO_4)_2(OH)_{14}$, III.

Borates

Suanite, $Mg_2B_2O_5$, II.
Kurgantaite, $(Sr,Ca)_2B_2O_8.H_2O$.
Tertschite, $Ca_4B_{10}O_{19}.20H_2O$, II?
Ivanovite, hyd. chloro-borate Ca(K?), II.
Volkovite, hyd. Sr,K, II.

Sulphates

Goldichite, $KFe(SO_4)_2.4H_2O$, II.
Görgeyite, $K_2Ca_5(SO_4)_6.H_2O$, II.
Mikheevite, $K_2Ca_4(SO_4)_5.H_2O$, I.
Nickel-epsomite, $(Mg,Ni)SO_4.7H_2O$, III.
Peligotite, $Cu(UO_2)_2(SO_4)_2.3H_2O$.aq.
Hidalgoite, $PbAl_3(SO_4)(AsO_4)(OH)_6$, VI.

Molybdate

Umohoite, hyd. U, VI.

[1] Only selected names given in the preceding alphabetical list are here included. Following A. E. H. Tutton (Crystallography, 1911, 1922) the crystal systems are indicated as: I triclinic, II monoclinic, III orthorhombic, IV tetragonal, V trigonal, VI hexagonal, VII cubic.

Phosphates, etc.

Avelinoite, $NaFe'''_3(PO_4)_2(OH)_4.2H_2O$, IV.
Barbosalite, $Fe''Fe'''(PO_4)_2(OH)_2$.
Lipscombite, $Fe''Fe'''(PO_4)_2(OH)_2$, IV.
Belovite, $(Sr,Ce)_{10}(PO_4)_6(O,OH)_2$, VI.
Bøggildite, $Na_2Sr_4A_2(PO_4)F_9$, II?
Cheralite, $(Ce,Th,U)(P,Si)O_4$, II.
Cyrilovite, $4Fe_2O_3.3P_2O_5.5\frac{1}{3}H_2O$, IV.
Faheyite, $(Mn,Mg,Na)Be_2Fe'''_2(PO_4)_4.6H_2O$, VI.
Faustite, $(Zn,Cu)Al_6(PO_4)_4(OH)_8.5H_2O$, I.
Hagendorfite, $(Na,Ca)(Fe,Mn)_2(PO_4)_2$, I?
Isokite, $CaMgPO_4F$, II.
Kahlerite, $Fe(UO_2)AsO_4.8H_2O$, II.
Laueite, $MnFe'''_2(PO_4)_2(OH)_2.8H_2O$, I.
Moraesite, $Be_2PO_4(OH).4H_2O$, II.
Ordoñezite, $ZnSb_2O_6$, IV.
Palermoite, $(Li,Na)_4SrAl_9(PO_4)_8(OH)_9$, III.
Parasymplesite, $Fe_3(AsO_4)_2.8H_2O$, II.
Shubnikovite, hyd. chloro-arsenate Cu,Ca,K, III?
Tavorite, $LiFe(PO_4)(OH)$.
Väyrynenite, $MnBe(PO_4)(OH,F?)$, II.
Vladimirite, $Ca_3(AsO_4)_2.4H_2O$, II?

Silicates

Beryllite, $Be_3SiO_4(OH)_2.H_2O$.
Coffinite, $U(SiO_4)_{1-x}(OH)_{4x}$, IV.
Ghassoulite, $Mg_3Si_4O_{10}(OH)_2$.
Grovesite, $(Mn,Mg,Al)_3(Si,Al)_2(O,OH)_9$, II?
Hexacelsian, $BaAl_2Si_2O_8$, VI (artif.).
Indialite, $Mg_2Al_4Si_5O_{18}$, VI.
Reedmergnerite, $NaBSi_3O_8$, I.
Wairakite, $CaAl_2Si_4O_{12}.2H_2O$, II.
Yugawaralite, $Ca_4Al_7Si_{20}O_{54}.14H_2O$?, II.

Titanates, Niobates, etc.

Alvarolite, $MnTa_2O_6$, II.
Irinite, $(Na,Ce,Th)(Ti,Nb)(O,OH)_3$, VII.
Nenadkevichite, $(Na,Ca)(Nb,Ti)Si_2O_7.2H_2O$, III
Shcherbakovite, $Na(K,Ba)_2(Ti,Nb)_2(Si_2O_7)_2$, II.

Hydrocarbons

Evenkite, $C_{12}H_{42}$.
Mirzaanite, var. of elaterite.
Stepanovite, $NaMgFe'''(C_2O_4)_3.8H_2O$.

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ee also List of new mineral names (p. 727). Only the main items are here indexed; for fuller details see Index to Mineralogical Abstracts, vol. 12.]

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